

# Space Ionization Radiation Environment and Effects (SIRE2) Model for Satellite Applications

## SEESAW Workshop

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Approved for Public Release  
17-MDA-9167 (2 May 17)

# Overview

- Why develop SIRE2?
- Tour of the Graphic User Interface (GUI)
- Example satellite calculations
- Future updates for SIRE2

# Why Develop SIRE2?

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- CREME96, SPENVIS, etc.
  - State of the art in their day
  - Environment models updates needed
- Address environments of space vehicles, UAV, and aircraft in arbitrary trajectory
  - Plans to incorporate atmospheric transport and address neutron environments
- Address needs for operation on corporate networks and desktop computers
- This work is being preformed in support of a Phase III SBIR

# Space Ionizing Radiation Environments and Effects (SIRE2)

## CREME 86/96

- Calculates satellite environments
- Environments models from mid 90's.
  - Geomagnetic Fields (CRÈME96-C96)
  - Trapped Radiation (AP8)
  - Cosmic Rays (C96)
  - Solar Particles (C96)
  - Radiation Shielding (C96+)
- Effects models also from the 80's/90's (C96)
  1. All CREME96 legacy environment models were updated in SIRE2 for space vehicles in flight.
  2. New SIRE2 environments models apply to interplanetary space, satellite, space vehicles, and other trajectories.
  3. SIRE2 user interface designed to maximize productivity and documentation. Results link with Microsoft Office via Visual Basic for Applications (VBA)
  4. Batch Model processing allows for a series for a variety of environment conditions and for large sets of piece parts

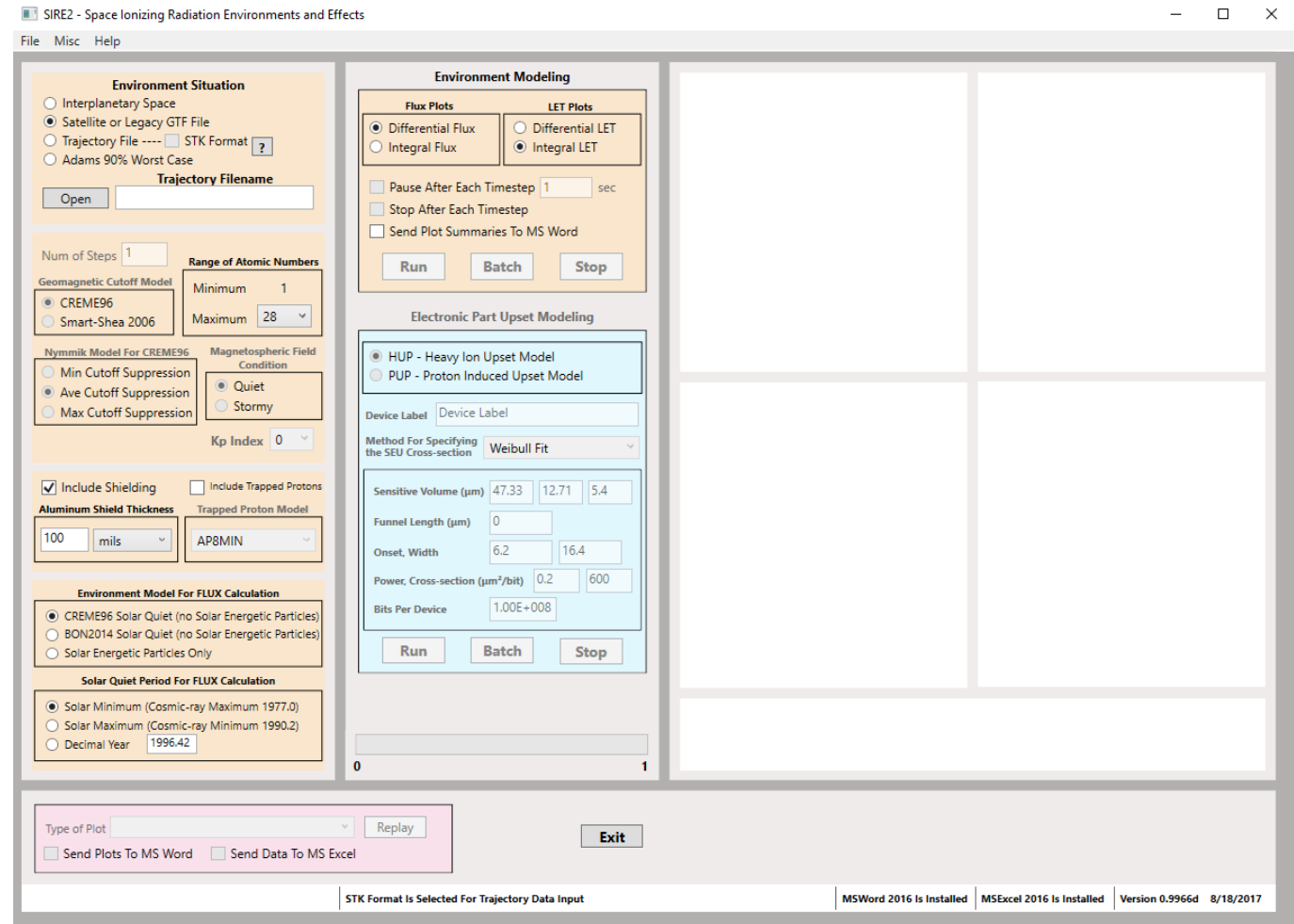
## SIRE2

- Calculates satellite, rockets, space vehicles, and other trajectory environments
- Environments models from mid 90's.
  - Geomagnetic Fields (C96+, SS06)
  - Trapped Radiation (AP8/AE8 & AP9/AE9 soon )
  - Cosmic Rays (C96/BON14)
  - Solar Particles (C96, RA17)
  - Radiation Shielding (C96+)
- Effects models also from the 80's/90's (C96 + plans for further upgrades)

# SIRE2 Capability

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- Environments
  - GTF
    - CREME-96
    - Smart-Shea 2006
  - Nymik Cutoff
    - Min, Max, Ave
  - Magnetic Field Conditions
    - Stormy
    - Quiet
  - Trapped Belt
    - AP8 Min/AP8 Max
    - AP9 TBD
    - AE9 TBD (dose only)
  - Flux Models
    - CREME96 Cosmic Rays
    - BON2014 Cosmic Rays
    - CREME96 Solar Particles
    - Robinson/Adams Solar Particles (Fall 2017)
- Batch mode processor always for a series of calculation



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### Environment Situation

Interplanetary Space  
 Satellite or Legacy GTF File  
 Trajectory File ----  STK Format   
 Adams 90% Worst Case

**Trajectory Filename**

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Num of Steps       Range of Atomic Numbers  
 Geomagnetic Cutoff Model      Minimum   
 CREME96      Maximum   
 Smart-Shea 2006

Nymmik Model For CREME96      Magnetospheric Field Condition  
 Min Cutoff Suppression       Quiet  
 Ave Cutoff Suppression       Stormy  
 Max Cutoff Suppression

Kp Index

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Include Shielding       Include Trapped Protons  
 Aluminum Shield Thickness      Trapped Proton Model  
      

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### Environment Model For FLUX Calculation

CREME96 Solar Quiet (no Solar Energetic Particles)  
 BON2014 Solar Quiet (no Solar Energetic Particles)  
 Solar Energetic Particles Only

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### Solar Quiet Period For FLUX Calculation

Solar Minimum (Cosmic-ray Maximum 1977.0)  
 Solar Maximum (Cosmic-ray Minimum 1990.2)  
 Decimal Year

### Environment Modeling

#### Flux Plots

Differential Flux  
 Integral Flux

#### LET Plots

Differential LET  
 Integral LET

Pause After Each Timestep  sec  
 Stop After Each Timestep  
 Send Plot Summaries To MS Word

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### Electronic Part Upset Modeling

HUP - Heavy Ion Upset Model  
 PUP - Proton Induced Upset Model

Device Label

Method For Specifying the SEU Cross-section

Sensitive Volume (μm)     
 Funnel Length (μm)   
 Onset, Width    
 Power, Cross-section (μm<sup>2</sup>/bit)    
 Bits Per Device

---

0 20

# Custom Satellite Orbital Parameters

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Satellite Orbital Parameters
- □ ×

File Help

Name Of Satellite Orbit GTRN Output File

Apogee  km ?

Perigee  km

Inclination  Degrees

Geomagnetic Cutoff Model

CREME96

Smart-Shea 2006

Starting Time (UT)

Year

Month

Day

Hour

Minute

Magnetospheric Field Condition

Quiet

Stormy

Kp Index

**Advanced Parameters**

Initial Longitude Of Ascending Node  Degrees

Initial Displacement From Ascending Node  Degrees

Displacement Of Perigee From Ascending Node  Degrees

Number Of Days To Average

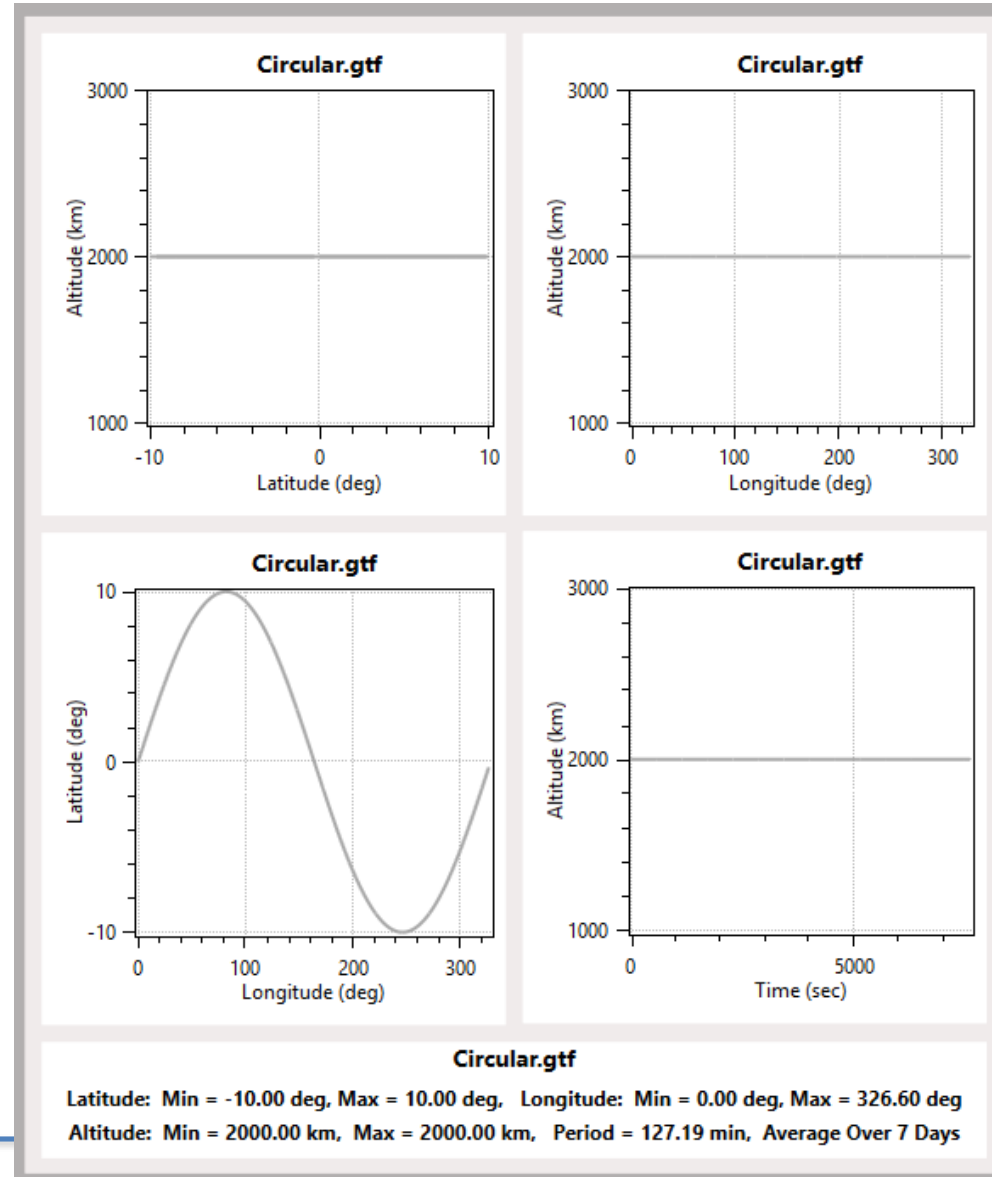
Number Of Steps Per Orbit

Number Of Orbits To Display

Create
Close

# 2000 Kilometer Circular Orbit

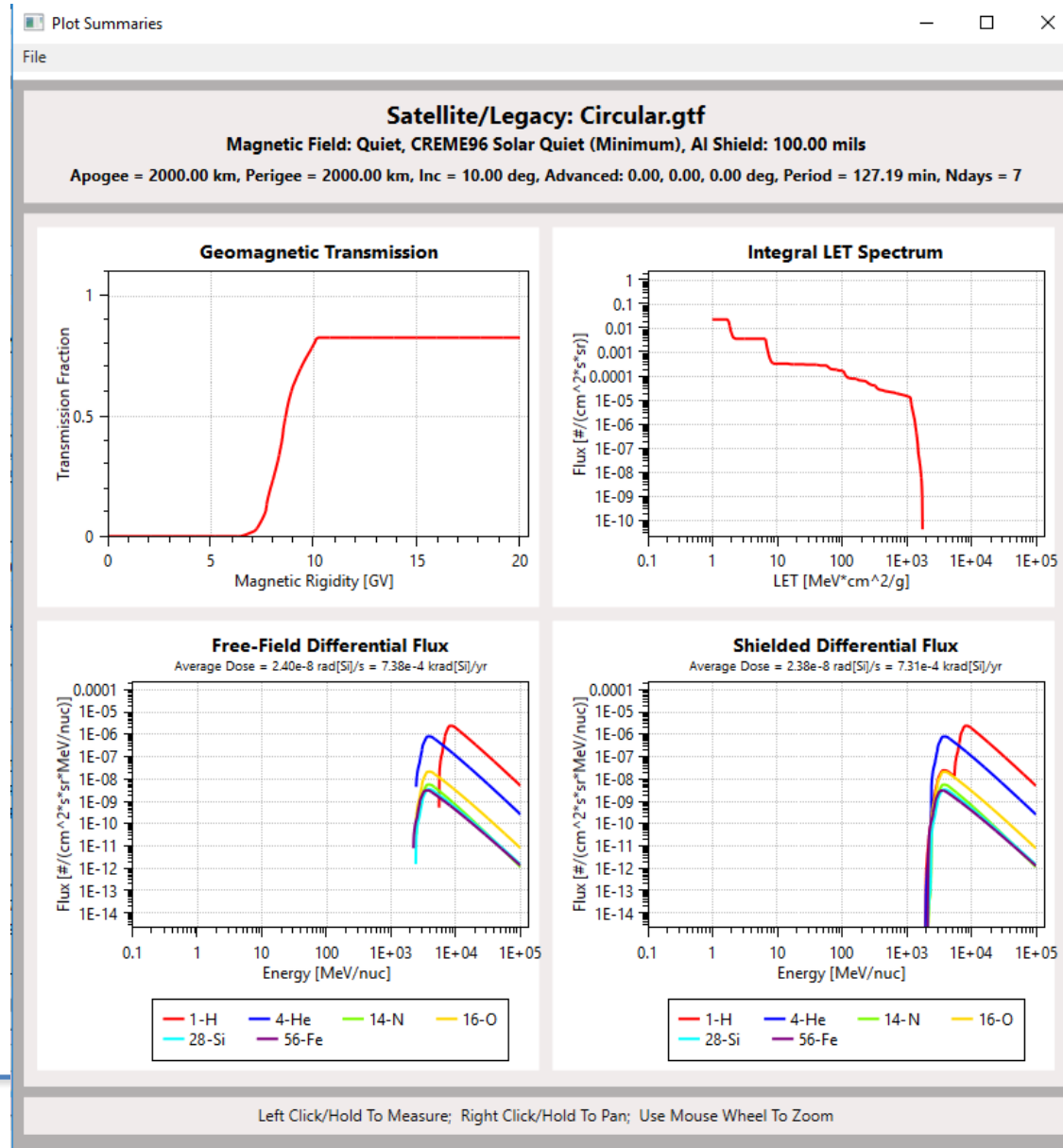
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# 2000 Kilometer Circular Orbit

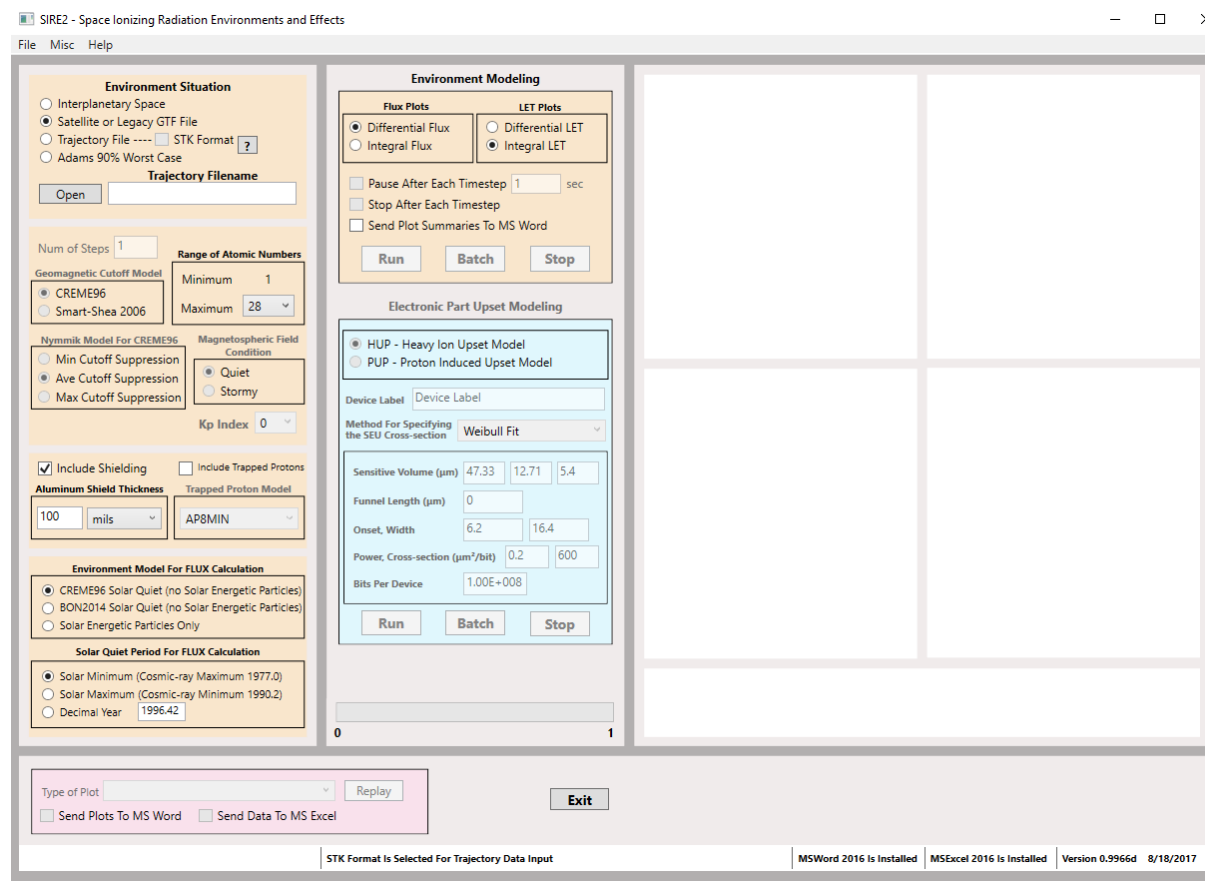
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# SIRE2 Capability

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- Electronic Upset models (legacy)
  - HUP
    - 2 Column
    - Weibull
    - Critical Charge
  - PUP
    - 2 Column
    - Bendel 1
    - Bendel 2
    - Weibull
- Updated Interface with Batch Mode Processor (SIRE2)
  - Excel or text input
  - Electronics Parts Template
  - Results saved in Excel and text format for later review



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### Electronic Part Upset Modeling

HUP - Heavy Ion Upset Model  
 PUP - Proton Induced Upset Model

Device Label

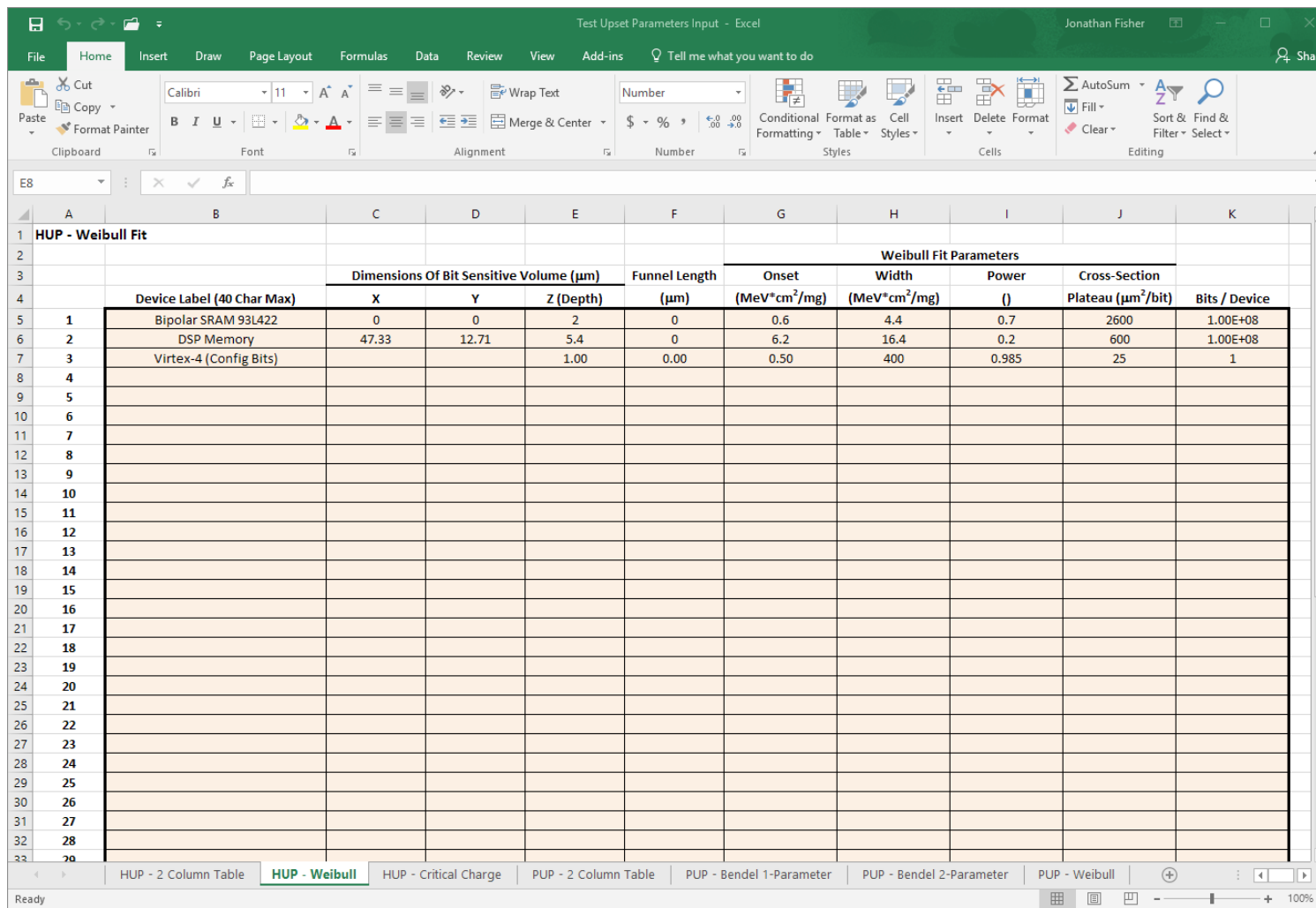
Method For Specifying the SEU Cross-section

Sensitive Volume ( $\mu\text{m}$ )	<input type="text" value="47.33"/>	<input type="text" value="12.71"/>	<input type="text" value="5.4"/>
Funnel Length ( $\mu\text{m}$ )	<input type="text" value="0"/>		
Onset, Width	<input type="text" value="6.2"/>	<input type="text" value="16.4"/>	
Power, Cross-section ( $\mu\text{m}^2/\text{bit}$ )	<input type="text" value="0.2"/>	<input type="text" value="600"/>	
Bits Per Device	<input type="text" value="1.00E+008"/>		

# SIRE2 Capability

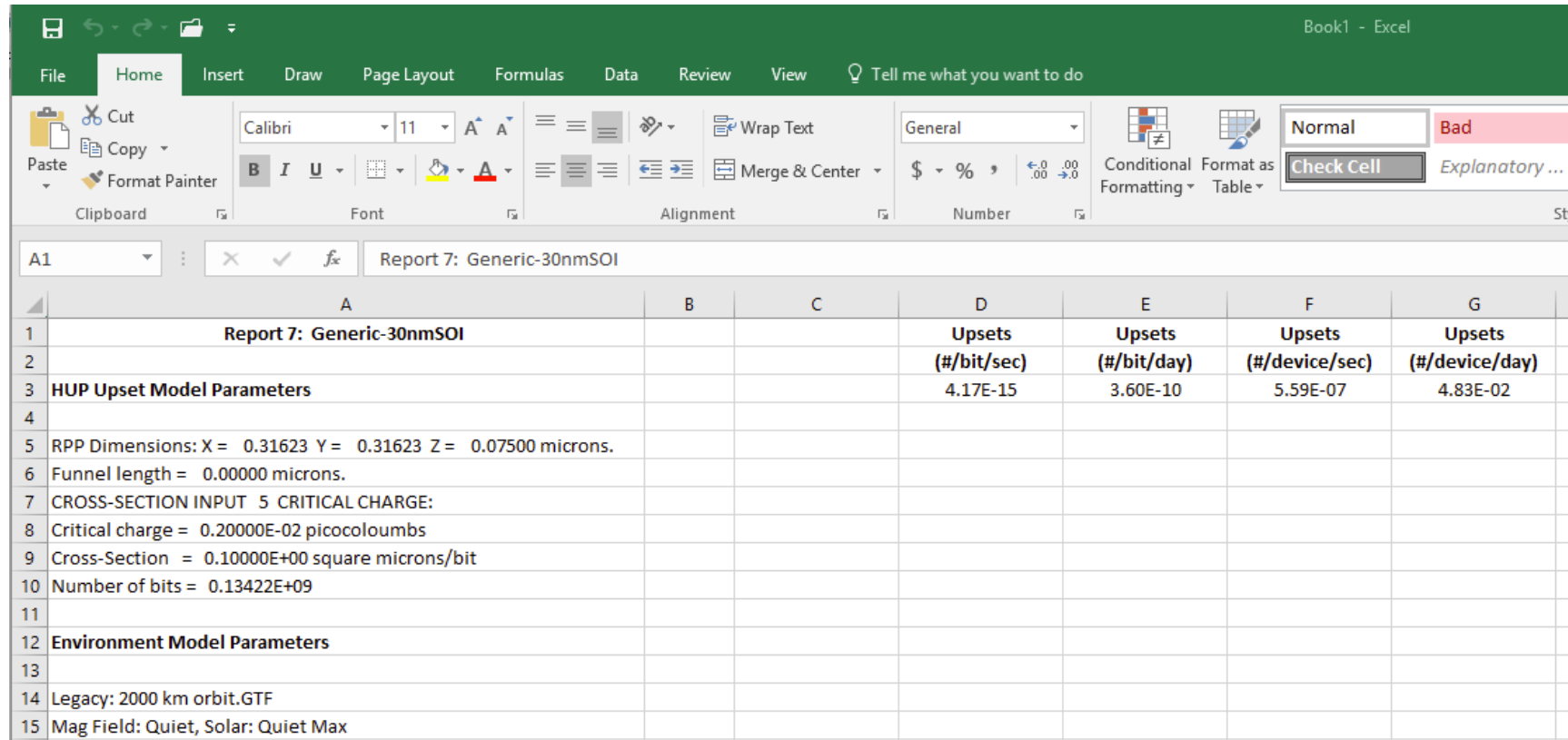
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HUP - Weibull Fit		Dimensions Of Bit Sensitive Volume (µm)				Funnel Length	Weibull Fit Parameters			
Device Label (40 Char Max)		X	Y	Z (Depth)	(µm)	Onset (MeV*cm <sup>2</sup> /mg)	Width (MeV*cm <sup>2</sup> /mg)	Power ()	Cross-Section Plateau (µm <sup>2</sup> /bit)	Bits / Device
1	Bipolar SRAM 93L422	0	0	2	0	0.6	4.4	0.7	2600	1.00E+08
2	DSP Memory	47.33	12.71	5.4	0	6.2	16.4	0.2	600	1.00E+08
3	Virtex-4 (Config Bits)			1.00	0.00	0.50	400	0.985	25	1
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# Single Event Upsets



	A	B	C	D	E	F	G
1	<b>Report 7: Generic-30nmSOI</b>			<b>Upsets</b>	<b>Upsets</b>	<b>Upsets</b>	<b>Upsets</b>
2				<b>(#/bit/sec)</b>	<b>(#/bit/day)</b>	<b>(#/device/sec)</b>	<b>(#/device/day)</b>
3	<b>HUP Upset Model Parameters</b>			4.17E-15	3.60E-10	5.59E-07	4.83E-02
4							
5	RPP Dimensions: X = 0.31623 Y = 0.31623 Z = 0.07500 microns.						
6	Funnel length = 0.00000 microns.						
7	CROSS-SECTION INPUT 5 CRITICAL CHARGE:						
8	Critical charge = 0.20000E-02 picocoloumbs						
9	Cross-Section = 0.10000E+00 square microns/bit						
10	Number of bits = 0.13422E+09						
11							
12	<b>Environment Model Parameters</b>						
13							
14	Legacy: 2000 km orbit.GTF						
15	Mag Field: Quiet, Solar: Quiet Max						

- Orbit averaged and/or time dependent upset rates recorded for each part including model parameters and environmental conditions

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# Future Updates to SIRE2

- Probabilistic Model
- AE9/AP9
- Increase calculation speed using callable DLL's and multiple core processing

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# How to Become Beta Tester

- Fill out contact information and make a request in the comments box

<http://www.5thgait.com/contact/index>

- Or email [zachary@5thgait.com](mailto:zachary@5thgait.com)

# References

- Tylka, Allan J, James H Adams, et al. 1997. “CREME96: A Revision of the Cosmic Ray Effects on Micro Electronics Code.” IEEE Nuclear Science 44 (6): 2150–2060.
- Fisher, Jonathan H., James H. Adams, et al,. 2014. “Space Radiation Environments Model Development for In-Flight Missile Solar Storm Radiation Environments, Engagement Studies, and Requirements Definition Contract Summary Report”. Fifth Gait Technologies, Huntsville, AL, Report FG2014-121.
- Adams, James H, Jonathan H Fisher, Zachary Robinson, Joseph H Nonnast, Robert Reed, Kevin Warren, and Brian Sierawski. 2017. “Space Ionizing Radiation Environment and Effects (SIRE2) Model for Satellite Applications.” In *Presented at the 2017 Single Event Effects Symposium in LaJolla, CA*. LaJolla, CA.