

-TID

/ firstbel@kari.re.kr

1.

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, 가 ,

(過度)

(不及)

(Transport)

3

3
(Monte Carlo)

NASA

2.

2.1

가 . 1
가

(Electromagnetic Radiation)

(Particulate Radiation)

, , , X ,

, , (高) 가

(Radiation Source)

(Inverse

Square Rule).

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, (低)

가

, , (Nuclei)

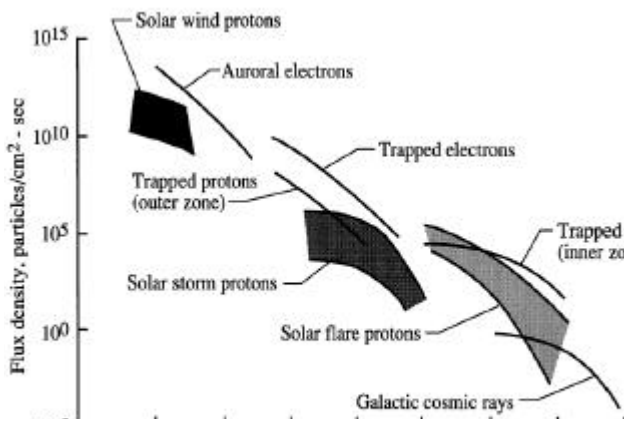
(TID : Total Ionizing Dose Effects)

(SEE : Single Event Effects)

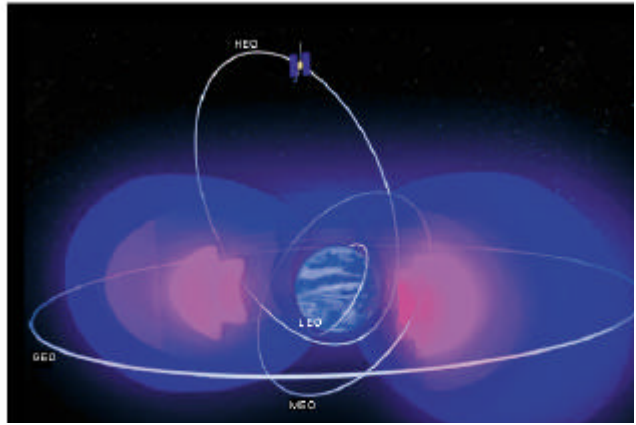
2.2

(Van Allen Belt), (Solar Flares)

(Galactic Cosmic Rays)



1. [2]



2. The VanAllen radiation belts and typical satellite orbits [3]

Space hazard	Spacecraft charging		Single-event effects			Total radiation dose		Surface degradation		Plasma interference with communications	
	Surface	Internal	Cosmic rays	Trapped radiation	Solar particle	Trapped radiation	Solar particle	Ion sputtering	O ⁺ erosion	Scintillation	Wave refraction
LEO <60°	Not applicable	Not applicable	Relevant	Important	Not applicable	Important	Relevant	Important	Important	Important	Important
LEO >60°	Relevant	Not applicable	Important	Important	Important	Important	Relevant	Important	Important	Important	Important
MEO	Important	Important	Important	Important	Important	Important	Important	Relevant	Not applicable	Important	Important
GPS	Important	Important	Important	Not applicable	Important	Important	Important	Relevant	Not applicable	Important	Important
GTO	Important	Important	Important	Important	Important	Important	Important	Relevant	Not applicable	Important	Important
GEO	Important	Important	Important	Not applicable	Important	Important	Important	Relevant	Not applicable	Important	Important
HEO	Important	Important	Important	Important	Important	Important	Important	Relevant	Not applicable	Important	Important
Inter-planetary	Not applicable	Not applicable	Important	Not applicable	Important	Not applicable	Important	Relevant	Not applicable	Relevant	Relevant

Important
 Relevant
 Not applicable

Crosslink Summer 2003, An Overview of the Space Radiation Environment, J. E. Mazur

3. Spaceenvironment hazards for typical orbits. [3]

Key : LEO<60 ? low Earth orbit, less than 60 degrees inclination;
 LEO >60 ? low Earth orbit, more than 60 degrees inclination;
 MEO? medium Earth orbit; GPS? Global Positioning System satellite orbit;
 GTO? geosynchronous transfer orbit; GEO? geosynchronous orbit;
 HEO? highly elliptical orbit; O⁺? atomic oxygen.

2.3

Damage),

2

2

가

(TID),

(Displacement

2.Radiation Effects and Parameters[4]

Effect	Parameter [Units]	Examples	Particles
Total ionizing dose (TID)	Ionizing dose in material [grays (Gy) or rads 1 Gy = 100 rads]	Threshold voltage shift and leakage currents in CMOS, linear bipolar (noted dose-rate sensitivity). Damage to materials. Creation of colour centers in optical media.	Electrons, protons, bremsstrahlung
Displacement damage	Displacement damage dose [keV/g or non-ionizing Gy or rads] Equivalent fluence of 10 MeV protons or 1 MeV electrons [cm ⁻²]	All photonics, eg CCD transfer efficiency, optocoupler gain Reduction in solar cell efficiency	Protons, electrons, neutrons, ions
Single event effects From ions	Events per unit fluence from linear energy transfer (LET) spectra & cross-section vs. LET [cm ² vs. MeV cm ² /gm]	Memories, microprocessors. Soft errors, latch-up, burn-out, gate rupture, transients in op-amps, comparators.	Ions
Single event effects from nuclear reactions	Events per unit fluence from energy spectra & cross-section versus particle energy [cm ² vs. MeV]	As above	Protons, neutrons
Payload-specific radiation effects	Energy-loss spectra, charge-deposition spectra [counts s ⁻¹ MeV ⁻¹]	False count rates in detectors, false images in CCDs	Protons, electrons, neutrons, ions, induced radioactivity (, [±] ,)
Biological damage	Dose equivalent = Dose (tissue) x Quality Factor [sieverts (Sv) or rems 1 Sv = 100 rem]	DNA rupture, mutation, cell death	Ions, neutrons, protons, electrons
Charging	Charge [coulombs (C)]	Phantom commands from ESD	Electrons

3.

3.1

(Top-level Radiation Environment)

(Nominal Aluminum Shield Thickness)

가

(Orbit-averaged Particle Flux Spectra)

(Dose-depth Curve)

? SPENVIS (ESA/ESTEC & BIRA-IASB) [5]

? SPACE RADIATION 5.0 [6]

3.2

(TID)

4

4

가 (: Deterministic

Method,

Monte Carlo or Stochastic Method)

).

? (3D Sectoring/ray trace)

:

- SPENVIS Sectoring Tool [5]

- ESABASE/RADIATION package [7, 8]

- SIGMA II [9]

- MEVDP [10]

? (Monte Carlo) :

- NOVICE [11]

- GEANT4 [12]

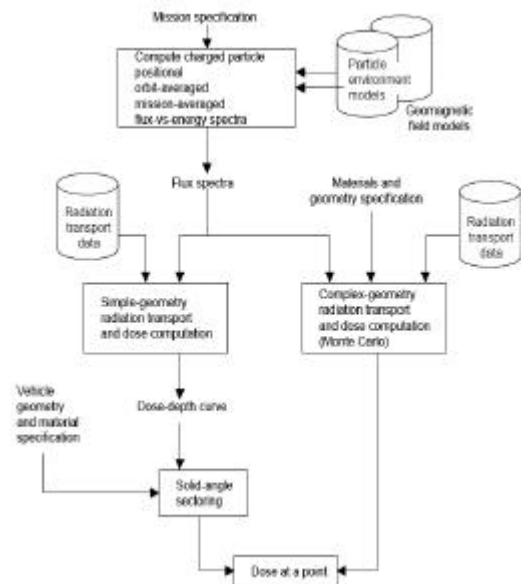
- FLUKA [13]

- HETC [14] and LCS(LAHET) [15]

- HZETRN [16]

- MCNPX [17]

- MULASSIS(SPENVIS & GEANT4) [5]



4. Radiation transport analysis overview [18]

3.3

3

(3D Sectoring/ray trace)

ESABASE/DOSRAD, SPENVIS

Sectoring Tool, SIGMA II . ESABASE/

DOSRAD

SHIELDDOSE

ESABASE/DOSRAD

5 (Ray Trace)
(Solid-angle Sectoring Method)

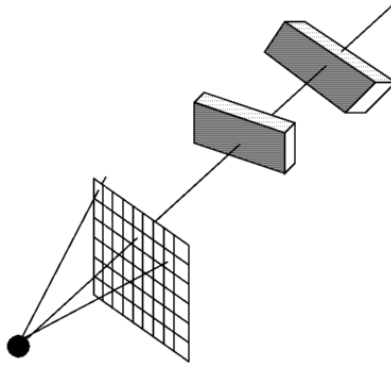
$d(t_i)$ (Sphere)
(Dose-depth Curve) t_i

()

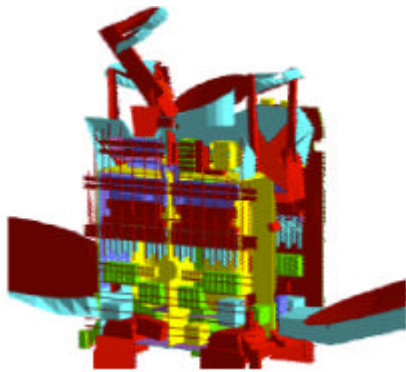
6 DOSRAD

7 DOSRAD

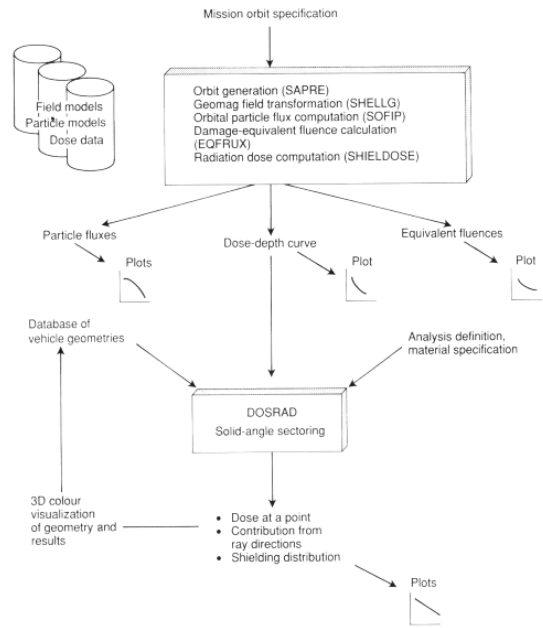
ESABA SE/RADIATION



5. (ESABASE/DOSRAD)



6. DOSRAD



7. ESABASE/RADIATION [19]

SPENVIS Sectoring Tool SIGMA II

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SIGMA II 100

SPENVIS Sectoring Tool

SPENVIS Sectoring Tool 6

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가

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5 6

KOREASAT 1/2

2005SAT

()

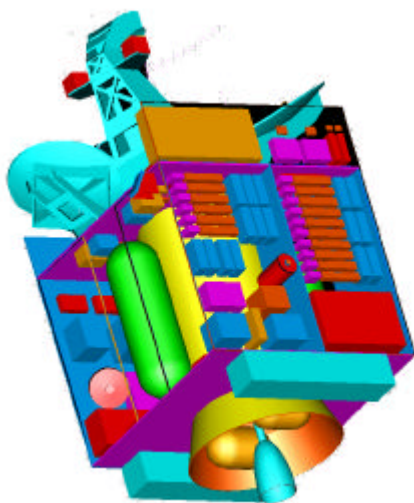
MEVDP(Modified Elemental Volume
Dose Program) 가 RSICC
CODE PACKAGE CCC-157

SPENVIS Sectoring

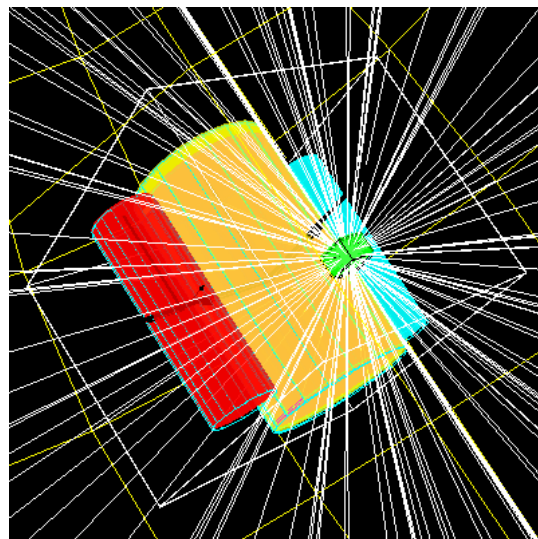
Tool

3. SPENVIS SectoringTool SIGMA II

항목	SPENVIS Sectoring Tool	SIGMA II
출력 (Output)	SOOF	TRF (Binary)
제작 (Author)	BRVAESA	ex McDonnell Douglas (Boeing)
제작 언어 (Language)	Web-based program	PC (FORTRAN)
제작 가능한 물체 (Object) (Geometric)	Using three elementary objects (sphere, cylinder, rectangular box, detector) up to 1	Quadratic surfaces up to 100
복합 물체 (Extent of object) (Extent of object)	Simple representation of spacecraft using geometric objects	Complex configuration using quadratic surfaces
물체 표현 (Method of object)	Solid angle sectoring with ray-tracing bill	Same as left
물체 표현 방법 (Method of object)	Not available	Simpson's rule
물체 표현 방법 (Method of object)	Interactive Window, VRML & Plain Text	Plain Text
사용 프로그램 (Interpreter) or Post (Language) (Language)	Orbit Explorer ⁽¹⁾ SHIELDOSE ⁽³⁾ or SHIELDOSE-S ⁽³⁾	OCSE ⁽¹⁾ CHARGE ⁽¹⁾
물체 표현 방법 (Method of object)	1	Up to 32
사용 언어 (User-friendly extent)	Easy	Hard (FORTRAN) Source Code
물체 표현 방법 (Method of object)	Not Applicable	Available but simple
비용 (Cost)	Free but registration required	\$ 400.0 (R200)



8. 2005SAT Model



9. A Simplified2005SATModel

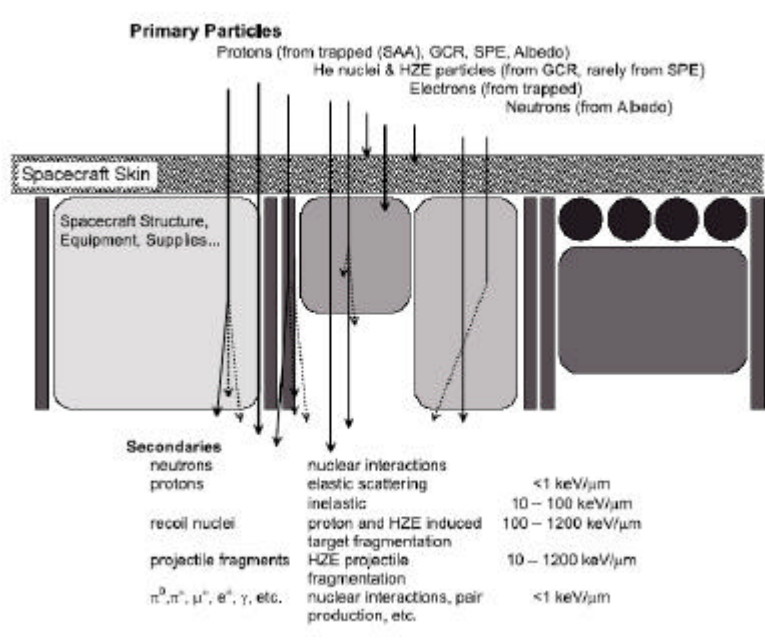
가 (Spot Shielding) 가 가
 , (Bremsstra (Electron's Path) 가
 hlung Angular Scatter), (Secondaries) ,
 (Background Particle (Electron Energy Loss)
 Levels) .[19] (Scattering Distri
 bution)
 3 (Section Length)

3.4

NOV
 ICE, GEANT4, FLUKA, HETC, HZETRN, MCNPX,
 LCS (LAHET), MULASSIS (SPENVIS & GEANT4)
 . NOVICE MULASSIS

3 NASA GSFC
 (Goddard Space Flight Center)

(Target)
 1,024
 가
 가 1,024 가
 가 (Random Sampling) 가 가
 가 (Electron) , () .[20]



10. The transport of primary radiation through the spacecraft structure and contents and the generation of secondaries. [21]

NOVICE
NOVICE 3

FLUKA
FLUKA 'Fluctuating Cascade'

(Reverse Monte Carlo Program)

FLUKA

1,024

(Heavy Ion; nuclei with 2)

[20]

가

FLUKA

[22]

HETC(High Energy Transport Code) and LCS(LAHET: The Los Alamos High Energy Transport)

GEANT4
GEANT4

Oak Ridge National Laboratory, HETC (Primary Particle) (Secondary Particles)

(Particle Cascade)

GCR

GEometry ANd Tracking GEANT4 'Toolkit' CERN (European Laboratory for High-Energy Physics)가 40 100

[23] LCS(LAHET Code System)

HETC 20 TeV 가

http://www.space.qinetiq.com/geant4/geant_dv.html

3-D

GEANT4 Sector Shielding Analysis Tool (SSAT) SSAT

(Induced Ionizing Radiation Environment)

(Radiation Background)

(Ray-tracing)

FORTRAN 77

[17] [26]

(Boundary Crossings) 가 (Fictitious Geantino Particle) 가 가

HZETRN(A Heavy Ion/Nucleon Transport Code for Space Radiations)

(Deep Space)

SSAT (Source code) GEANT4 LINUX C++ Windows PC 가

NASA LRC (Langley Research Center) HZETRN

HZETRN (Cross sections)

<http://see.msfc.nasa.gov/tda.htm>

An Efficient HZETRN (A Galactic Cosmic Ray Transport Code) NASA Technical Paper 3147

(Preliminary Phase)

(Verification Phase)

3

MCNPX(Monte Carlo N-Particle Transport Code System)

3

MCNPX CCC-660/MCNP4B

가

[29]

Los Alamos National Laboratory APT(Accelerator Production of Tritium)

3

[24, 25]

MULASSIS(SPENVIS & GEANT4)

SPENVIS

SPENVIS Sectoring Tool

MULASSIS(MULti-LAYered Shielding Simulation Software) 1

PC

가

(Incident Particle Source)

GEANT4

Toolkit

SPENVIS Sectoring Tool 6

Elemental/Isotopic

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GEANT4

GEANT4, MCNPX LCS
ESABASE/RADIATION NOVICE

가

가

SPENVIS

가

SPENVIS

GEANT4

(Non-Ionising Energy Loss, NIEL)

, Windows

(Pulse Height Spectrum,

PHS)

MCNPX LCS

[27] [28]

가

4.

NASA Office of Biological and Physical Research (OBPR) NASA

Space Radiation Shielding Program

NASA Space Radiation Transport Code Development Consortium

(, ,)

가

NASA

가

(2007 4)

HETC FLUKA

가 (Heavy Ion Transport)
HZETRN 3

.[30]

FLUKA : Fluctuating Cascade
GCR : Galactic Cosmic Rays
GEANT : GEometry ANd Tracking
GEO : Geosynchronous Orbit
GPS :Global Positioning System
GTO : Geosynchronous Transfer Orbit
HEO : Highly Elliptical Orbit
HETC : High Energy Transport Code
HZE particles : HighMassandEnergy(Z=atomic
number,E=energy)
LAHET : Los Alamos High Energy Transport
LCS : LAHET Code System
LEO : Low Earth Orbit
LET : Linear Energy Transfer
MCNPX : Monte Carlo N-Particle Transport Code
System
MEO : Medium Earth orbit
MEVDP : Modified Elemental Volume Dose Program
MULASSIS : MUlTI-LAYered Shielding SImulation
Software
NIEL : Non-Ionising Energy Loss
OBPR : Officeof Biological and Physical Research
SEE : Single Event Effects
TID : Total Ionizing Dose Effects

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