The 6th Mission Idea Contest
For Achieving Sustainable Development Goals with Human Spaceflight

On-orbit Measurements of Radiation Effects on Commercial-Off-The-Shelf (COTS) Hardware for Small Satellites

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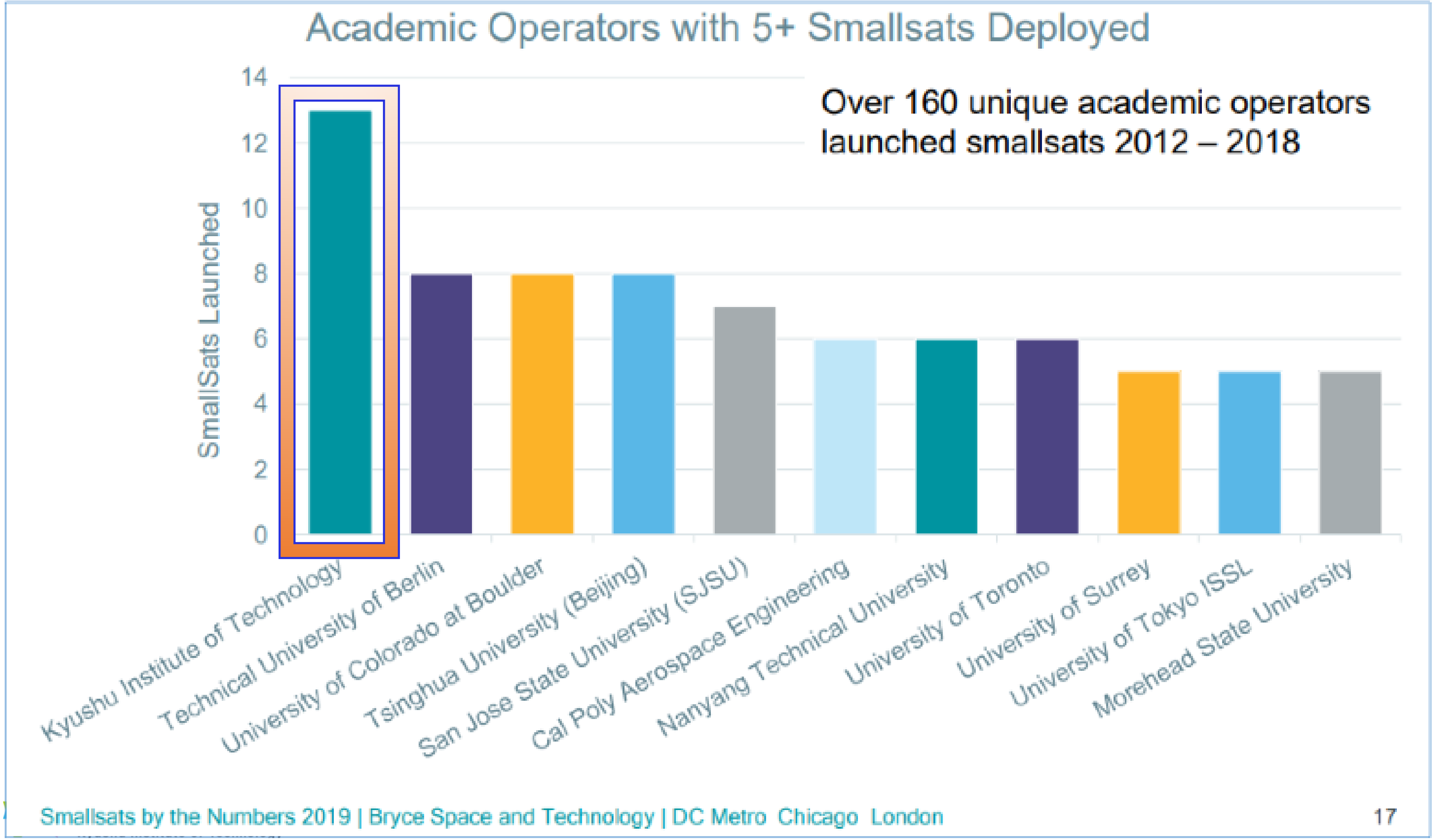
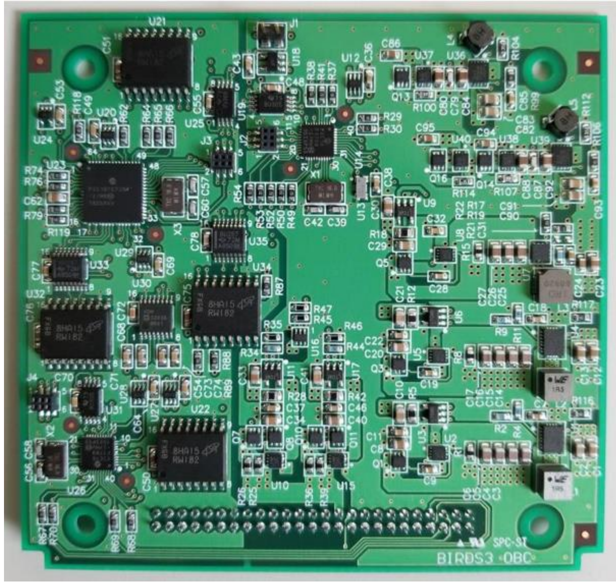
Laboratory of Spacecraft Environment Interactions Engineering

Introduction (1/5)



Introduction (2/5)

- We use COTS components in most subsystems.
- Why COTS?
  - Low cost
  - Fast delivery
- Demerits
  - High risk approach
  - Not space-proven/radiation-hardened



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CPU(PIC)

MOSFET

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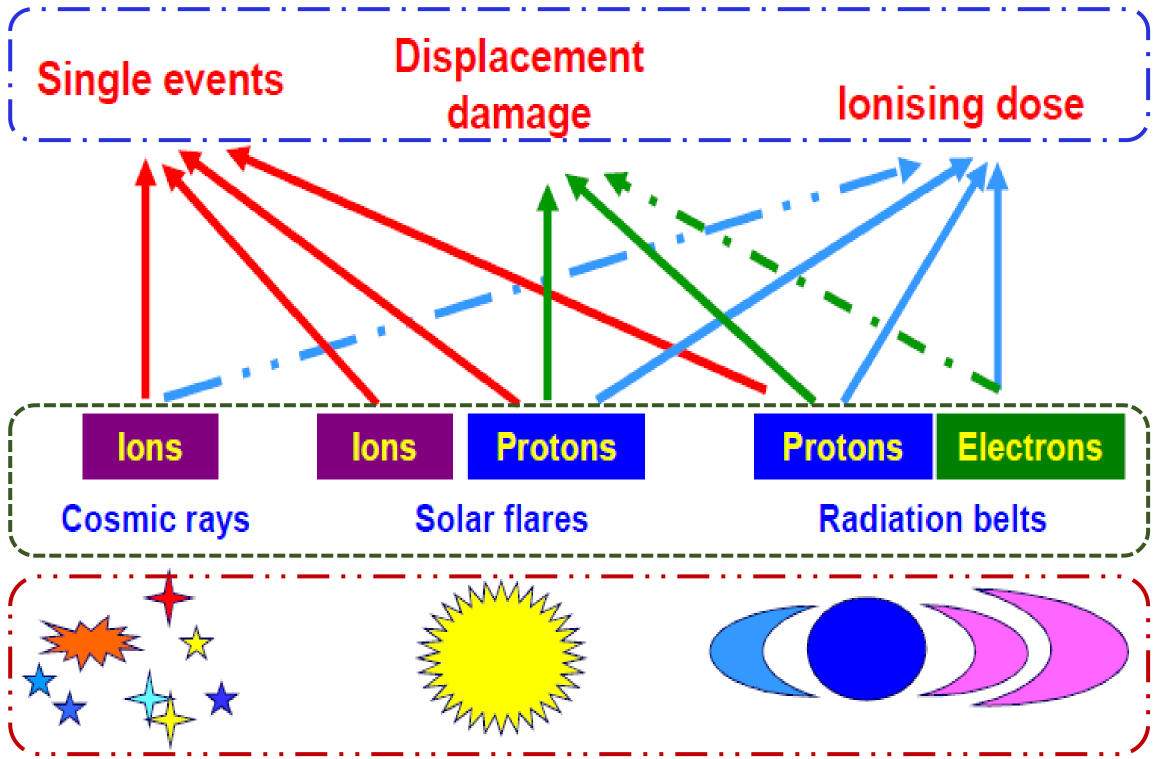
Introduction (3/5)

Effect of radiation on electronic devices

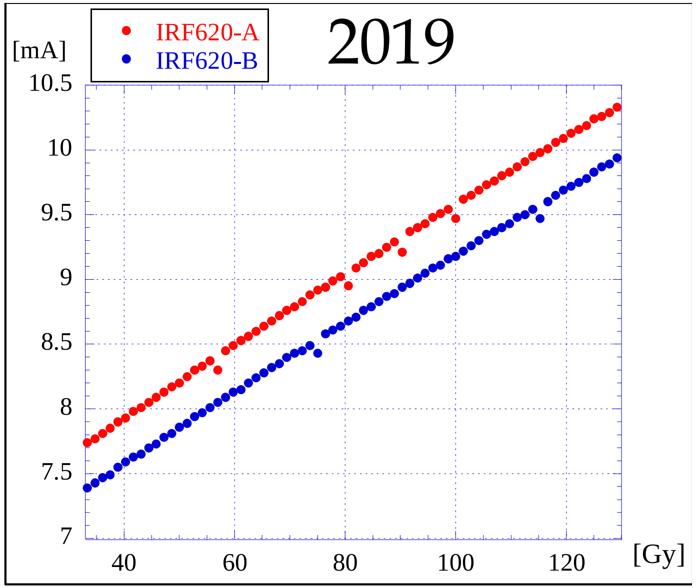
- effects
- particles
- sources

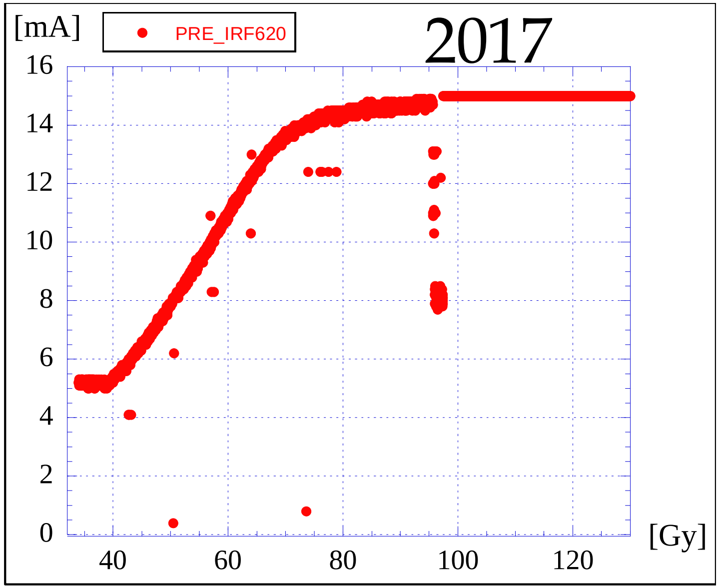


Introduction (4/5)

To manage the risk, we irradiate COTS components

Present results





Next step

Implementation of irradiation of COTS components onboard ISS under actual space conditions from the viewpoint of checking the accuracy of ground test

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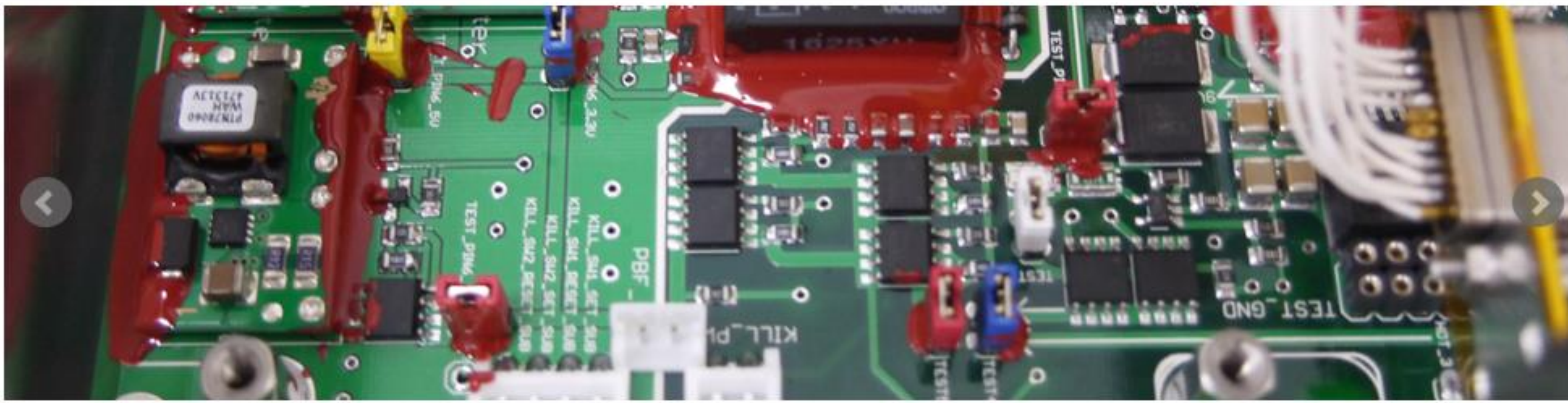
Introduction (5/5)

Consumer parts database on micro satellite

Citizenship Satellite Initiative for Connected Industries

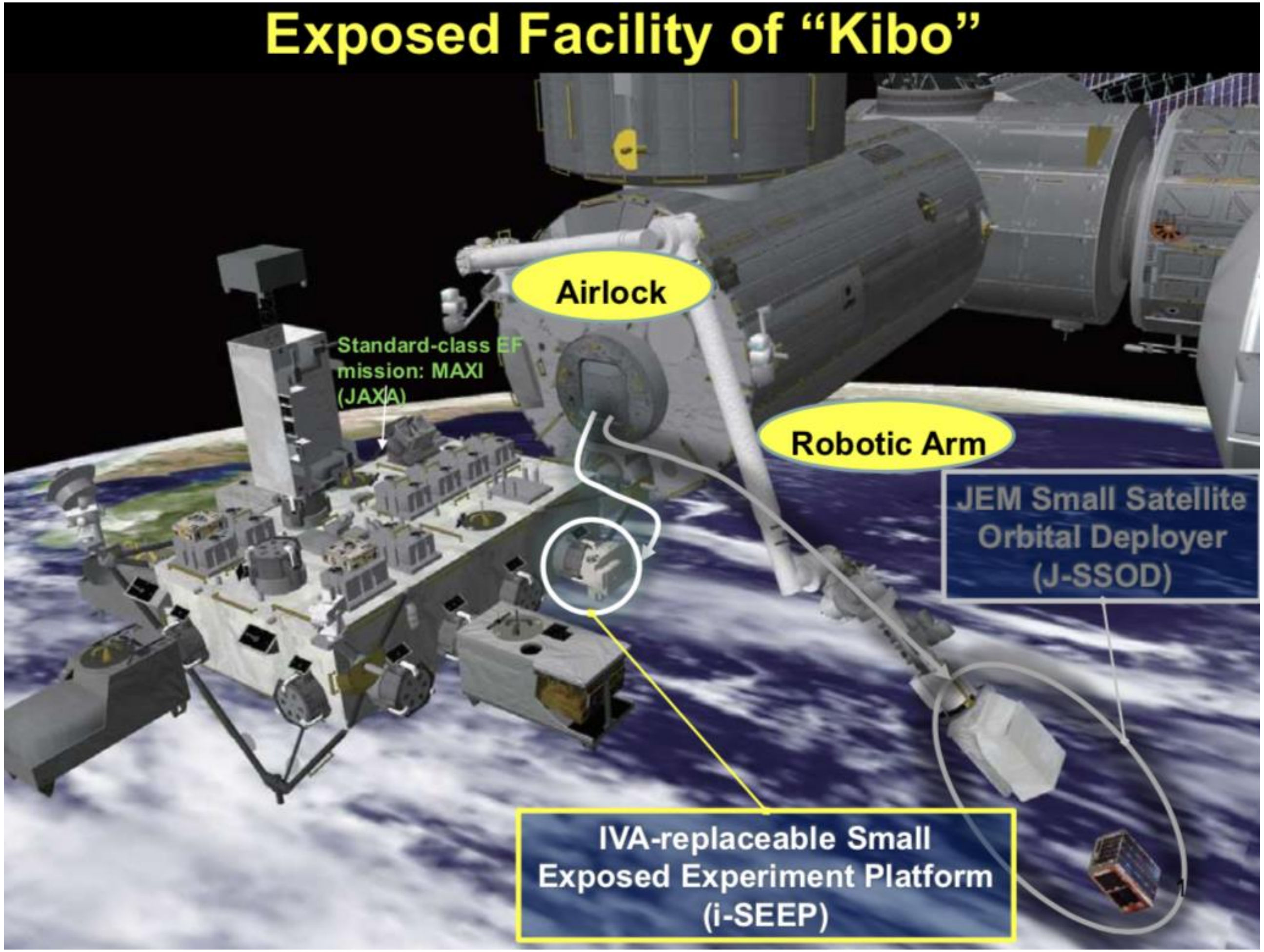
| **Satellite list** | About the database | New registration application | Search page | How to import CSV data |

| Contact Us | Publication | FAQ |



(https://space-cots-data.jp/)

Testing Platform



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Mission Statement

To develop and launch a 3U CubeSat, named **SPA**ce **R**adiation e**X**posure (SPARX), and perform the **CO**TS **I**rradiated i**N** **S**pace (COINS) experiment onboard ISS, particularly in-situ measurements of total ionizing doze and on-orbit mapping of single event latchup, providing a testbed for advanced technology demonstration with a hyperspectral imager and gathering scientific data for 1 year (nominal mission duration).

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Scientific Objectives

- To verify the radiation tolerance of power MOSFETs under actual space radiation environment

- To measure and map single-event-latchup in orbit by taking log of microcontroller reset events over a period of time

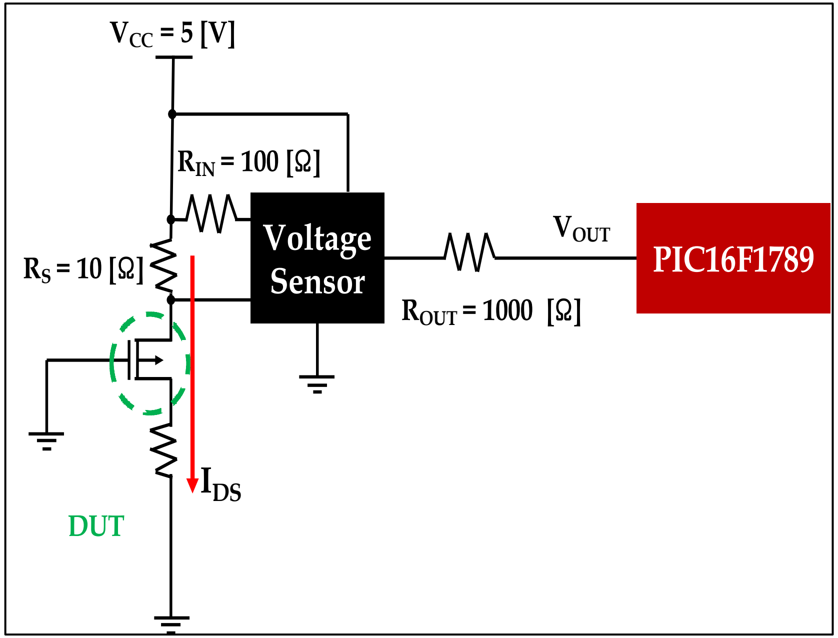
- To compare Earth-based testing techniques such as Cobalt-60 gamma radiation and Californium 252 (Cf 252) with on-orbit radiation data

Technological Objective

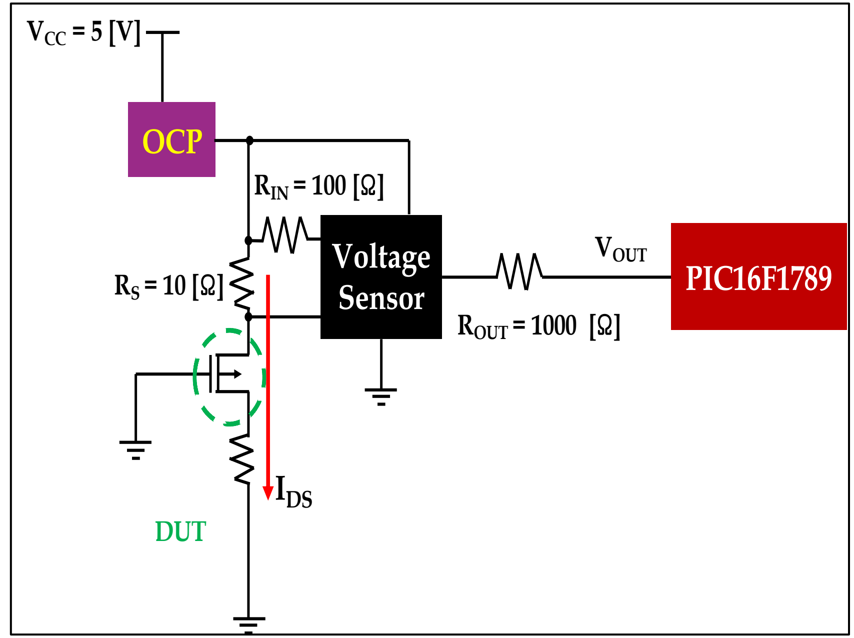
- To demonstrate hyperspectral imaging of tropical cyclones in the Indian Ocean between Madagascar and the Mozambique channel with a CubeSat

https://www.worldvision.org/disaster-relief-news-stories/2019-cyclone-idai-facts

Experimental Concept



Ground-testing setup



Space-testing setup

Key Performance Parameters

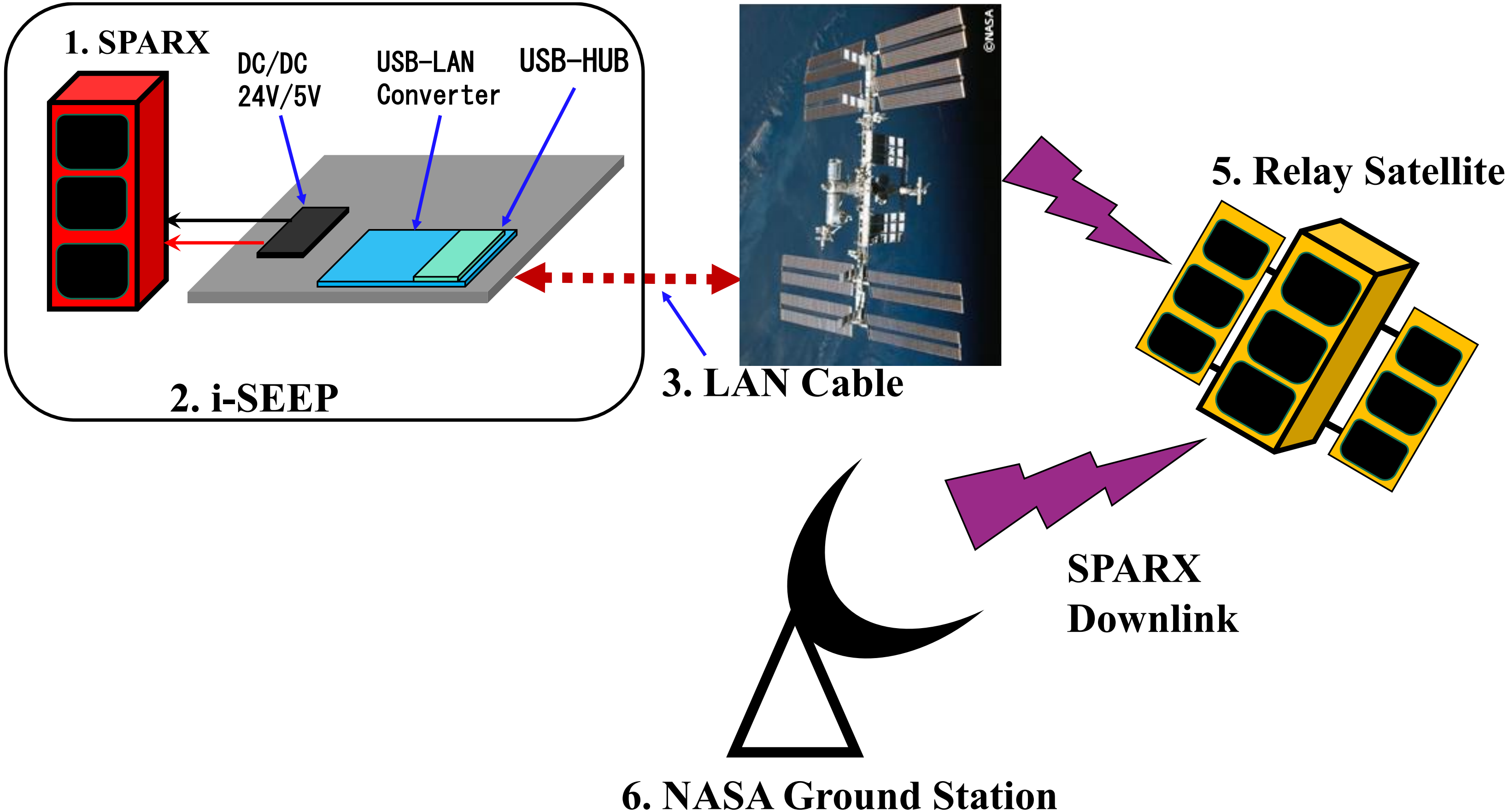
Functional Requirements

- The mission shall withstand deployment forces, vibration, and fluctuating operation temperatures
- The mission shall survive a total dose equivalent to 30 krad

Performance Requirements

- The structural frame shall be compliant with 3U CubeSat standards
- Uninterrupted electrical power shall be sourced from i-SEEP via USB cable and peak power consumption shall not exceed 50 W
- The on-board computer shall transfer scientific data from flash memory to i-SEEP via Ethernet (IEEE 802.11n) and data rate shall not exceed 100 kbps

Space Segment (1/5)



Space Segment (2/5)

Test Articles for Single Events

PIC18F67J94

H8

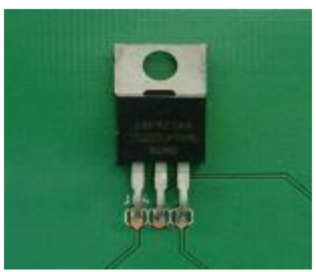
PIC18F97J60

Ground-testing data for most these microcontrollers are currently available

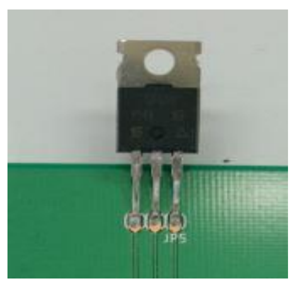
Space Segment (3/5)

Test Articles for Ionizing Doze

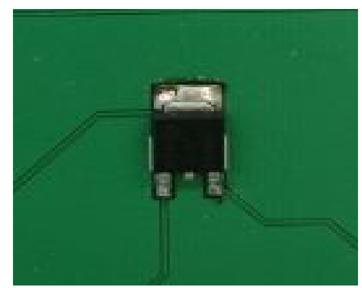
MOSFET	P- Channel IRLML6402	N-Channel IRF620PBF	P-Channel NTD2955
Power consumption	153.0 mW	46.05 mW	49.06 mW
Manufacturer	International Rectifier	Vishay	ON Semiconductor



Pch
IRLML6402



Nch
IRF620PBF



Pch
NTD2955

Space Segment (4/5)

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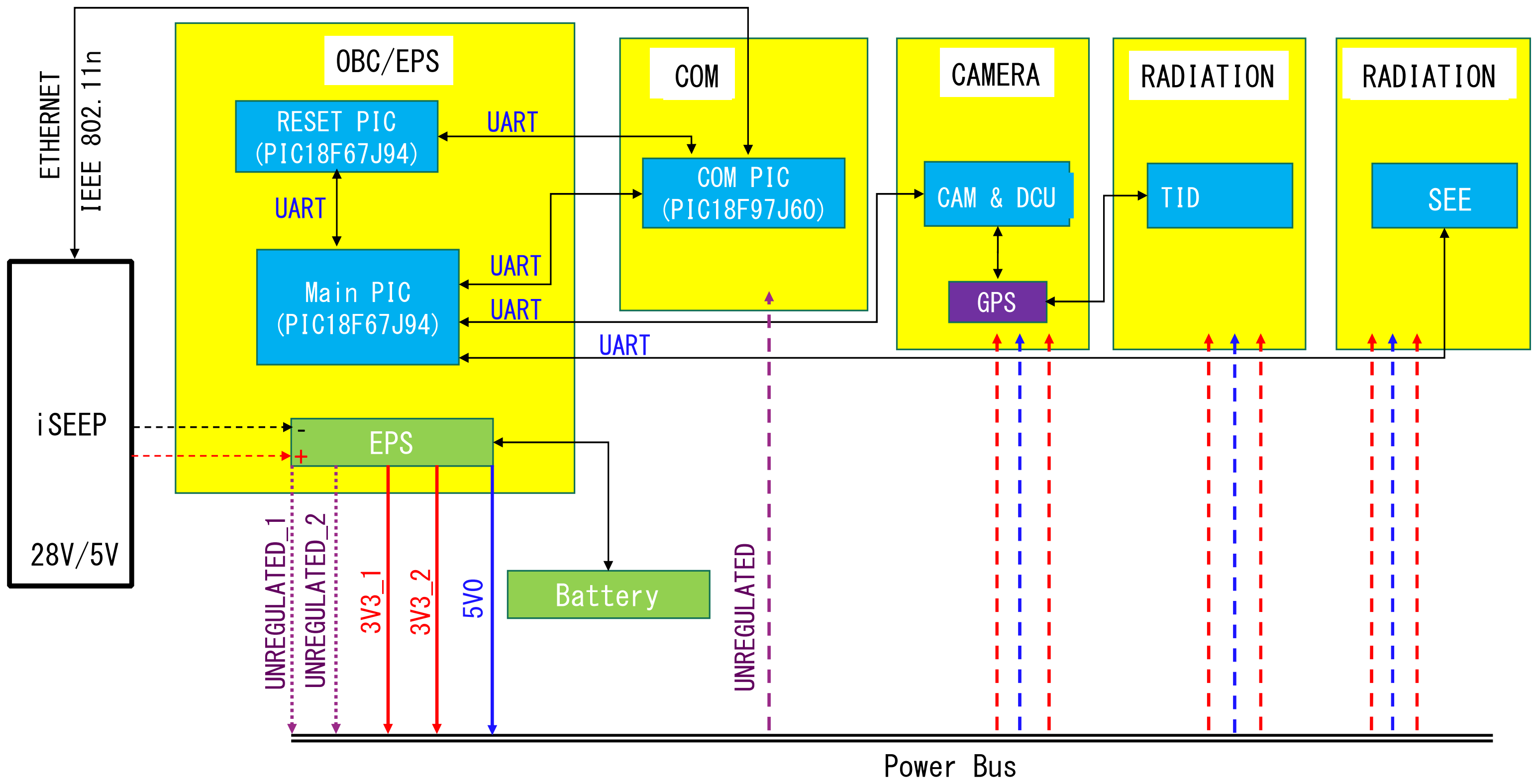
SPARX's Block Diagram



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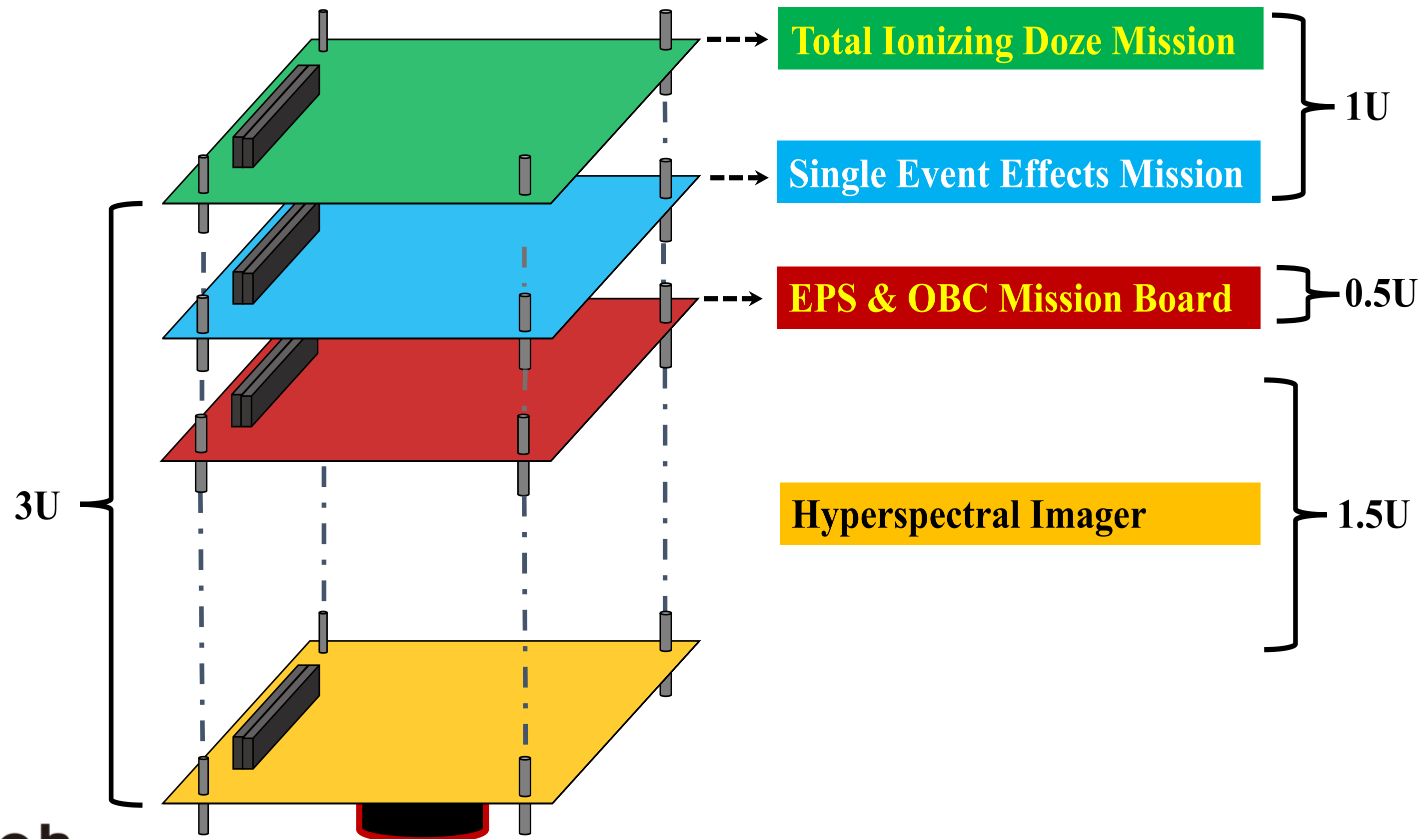
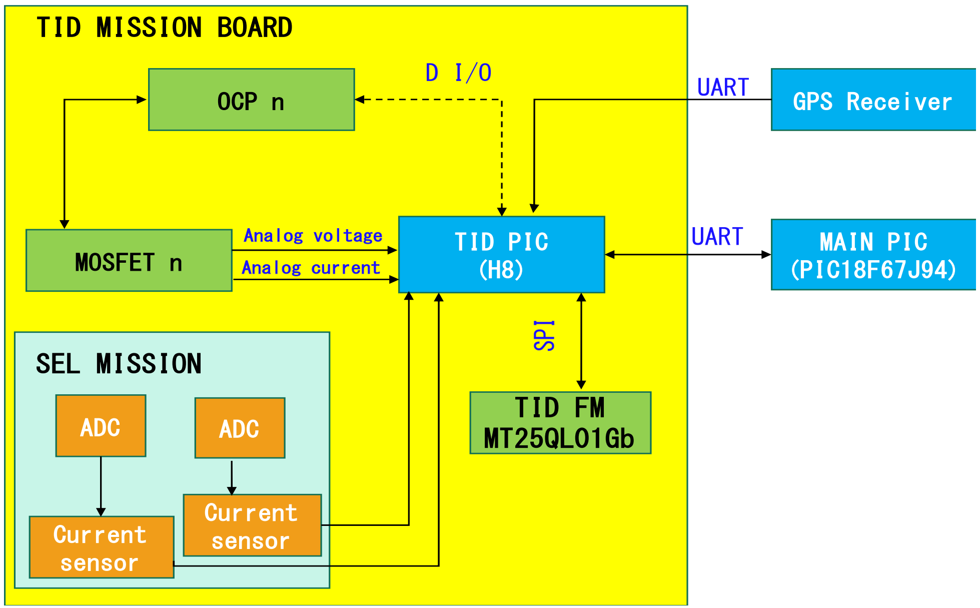
Space Segment (5/5)

Mission Boards Sequence



Concept of Operations (1/2)

Radiation Mission



- Measure the currents and voltages of power MOSFETs.
- Save science data to local flash memory (TID FM).
- Science data from TID FM is sent to OBC (MAIN PIC)
- MAIN PIC sends science data to PIC18F97J60 microcontroller (IEEE 802.3 compatible)
- PIC18F97J60 transfers science data to iSEEP via Ethernet.

Concept of Operations (2/2)

Hyperspectral Imager

VIS-NIR spectral range	**High frame rate RGB Matrix imager or Multispectral line scanning imager or Hyperspectral line scanning imager**
Spatial Resolution	9.6m at 500 km
Swath	32 km at 500km
Spectral Bands Multispectral	PAN + up to 10 VIS-NIR bands or RGB Bayer matrix or 150 Hyperspectral bands
Integrated mass storage	160 GB
Power consumption	during readout mode < 2.5W during imaging mode < 3.5W

Implementation Plan

Project Costs and Partners

Task /Item	Cost (USD)	Financer
COTS Components + 3U Chassis + PCBs Fabrication	6700	National Commission on Research Science and Technology
Hyperspectral Imager	160,000	Mozambique National Meteorology Institute + African Union
Environmental Testing	30,000	LaSEINE
H3 Launch Vehicle + i-SEEP Facility + Payload Return +	419,754.50	JAXA WMO Crowd Funding
Total	**616, 454.50**	

Risks and Countermeasures

Risk	Probability	Countermeasure
Single Event Upsets	Medium	Error Correction Code (ECC)
Single Event Latchup	Medium	Power Cycling/Periodic Restarts
Flash Memory Failure	High	Redundant Memories
Single Event Burnout	Medium	Shielding
Large Data Rate	High	Onboard Data Compression

Project Organization

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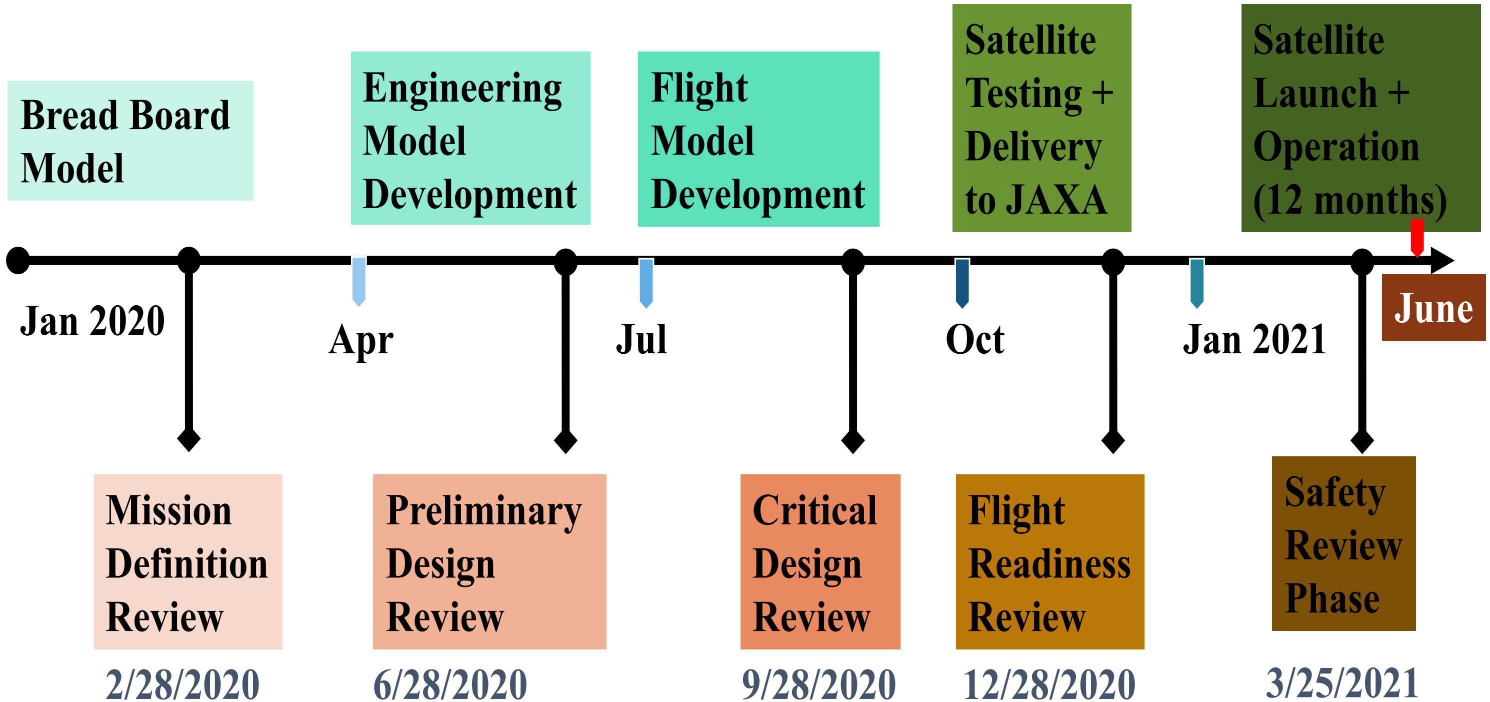
SPARX Non-Product Elements

- System Engineering
  - Requirement Management
  - Risk Management
  - Production Management
  - Verification Management
  - Interface Management
- Project Management
  - Schedule Management
  - Procurement Management
  - Sponsorships Management
- Services
  - Outreach
  - Marketing
  - Safety Review

Project Timeline



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thank you
شكراً جزيلاً
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рахмат
danke
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spas
teşekkür ederim
Баярлалаа
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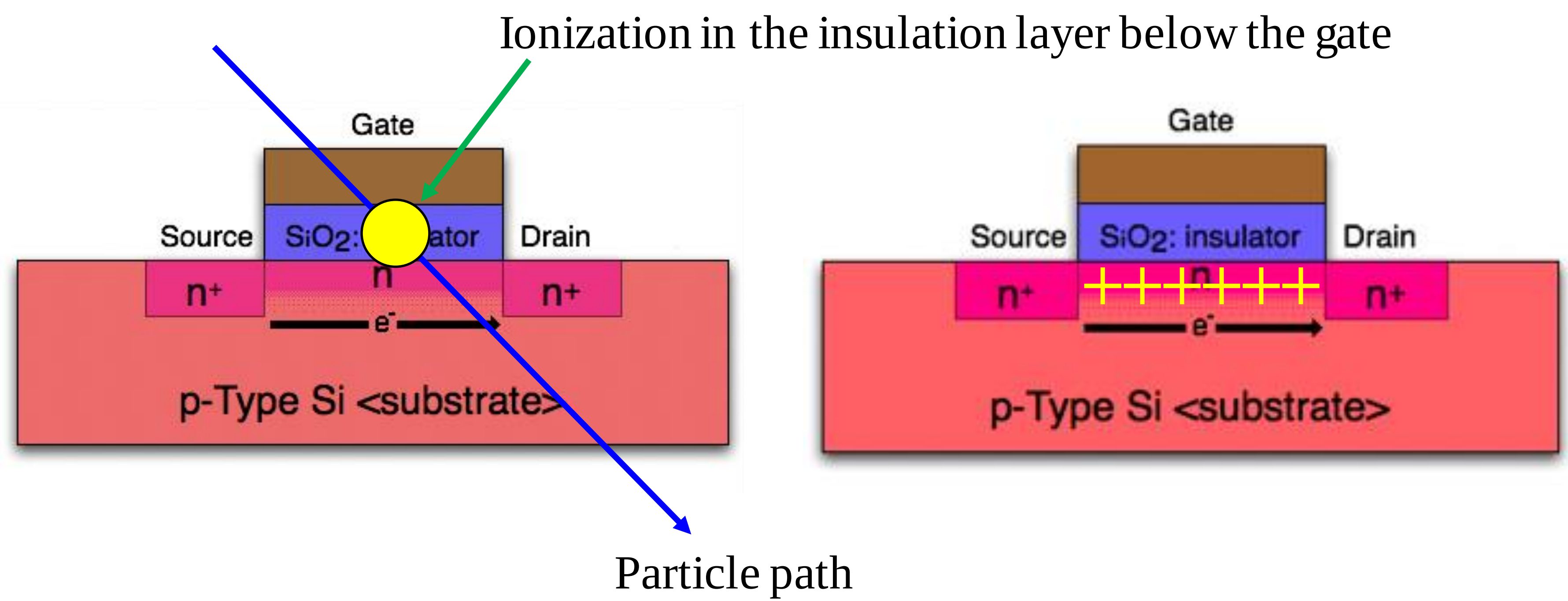
Introduction (4/5)

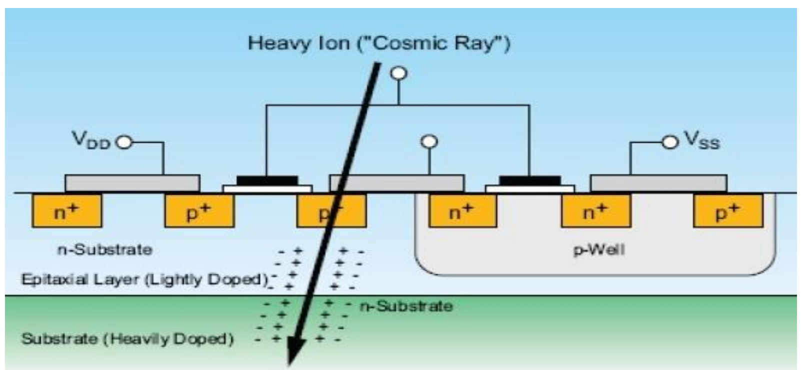
Total Ionizing Doze



Introduction (4/5)

Single Event Latchup (SEL)

– An abnormal high-current state in a device caused by the passage of a single energetic particle through sensitive regions of the device structure and resulting in the loss of device functionality



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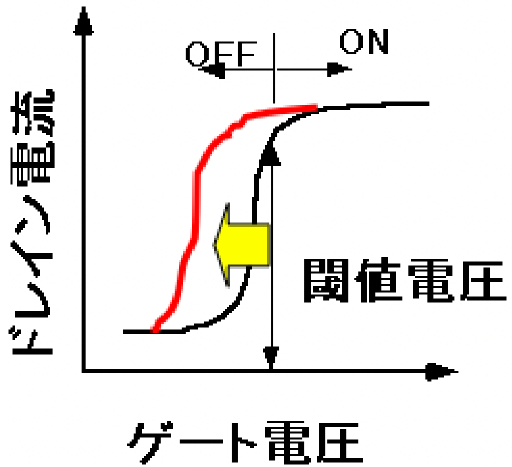
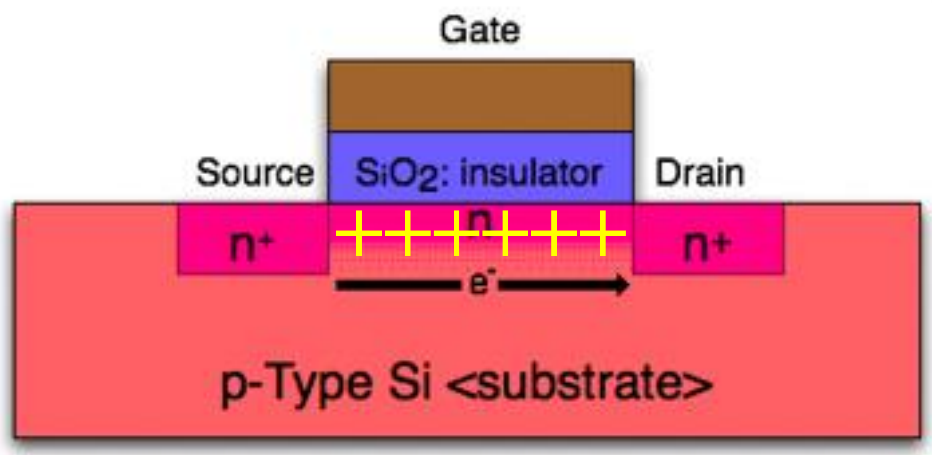
Introduction (5/5)



MOS-FETの動作特性



- The gate needs less voltage to turn on the switch by the positive voltage produced by the remaining positive charge
- Decrease of the threshold voltage
- Change of MOS operational points
- The effect disappears as the holes move away from the insulation layer
- – Takes a long time(>10^8 sec)

Single Event Effects (SEE)

- Disruption in function of electronic circuits due to single ionizing particle interaction.

  - **Single Event Upset (SEU)** – bit flips
  - **Single Event Latchup (SEL)** – parasitic
  - **Single Event Functional Interrupt (SEFI)**
    • Soft error, can be recoverable without power reset, unlike SEL
  - **Single Event Burnout (SEB)**
    - Current induced by heavy ion penetration destroys Power MOSFET
  - **Single Event Gate Rupture (SEGR)**
    • Failure of oxide layer of Power MOSFET by current

Doug Sinclair and Jonathan Dyer, "Radiation Effects and COTS Parts in SmallSats", Small Satellite Conference, 2013

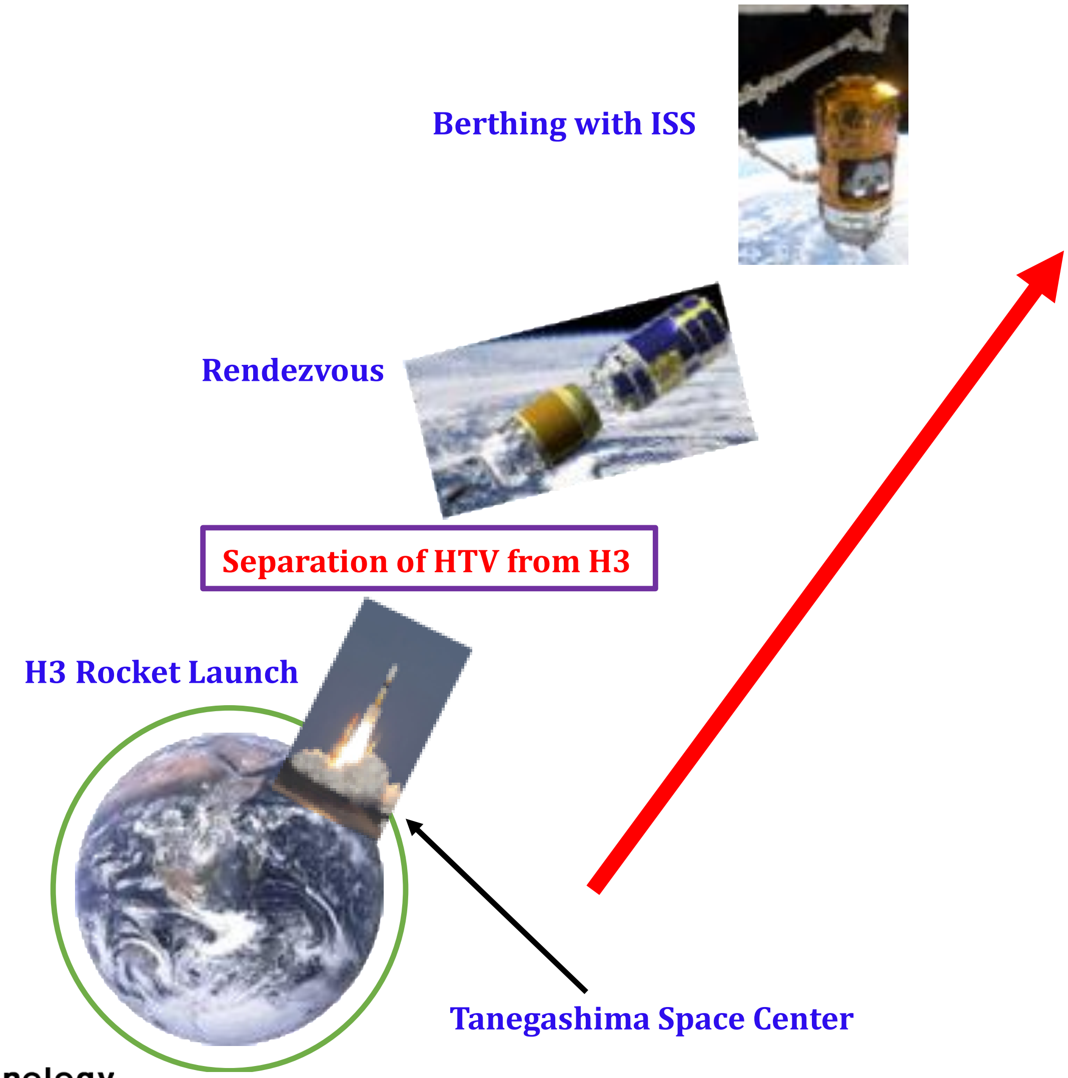
Space Radiation

La SEINE

- **Particles** or **electromagnetic** wave with energy high enough to affect chemical or nuclear properties of material.
- **Charged particles**
  - Electron
  - Proton
  - Alpha particle (nucleus of Helium)
  - Heavy ions
- **Particle**
  - Neutron
- **Electromagnetic wave (photon)**
  - Gamma ray, typically less than 10-12m (>1MeV)
    - – Originate from nuclear interactions
  - X ray, typically 10-11 ~ 10-8 m (100~100keV)
    - Originate from collisions of charged particles
  - UV ray, typically 10nm ~ 380nm (3eV~100keV)

Launch & Rendezvous to ISS

La SEINE



Definitions

Radiation Effect	Total Ionizing Doze (TID)	Single Event Effects (SEE)	Displacement Damage
Definition	Material damage caused by ionizing radiation sources. Qualified by deposited energy per mass for a given material with units of Gray (SI) or Rad [1].	Disruption in function of electronic circuits due to single ionizing particle interaction [1].	Change of semiconductor properties such as carrier lifetime due to protons and energetic electrons.
Degree of impact	Cumulative (Semi-infinite)	Abrupt (Transient)	Cumulative (Non-reversal)