# In-situ Measurements of the Cosmic Radiation on the Aircrew over Korean Peninsula

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# CONTENTS


- Introduction
- Methodology
- Analysis Results
- Summary

# INTRODUCTION

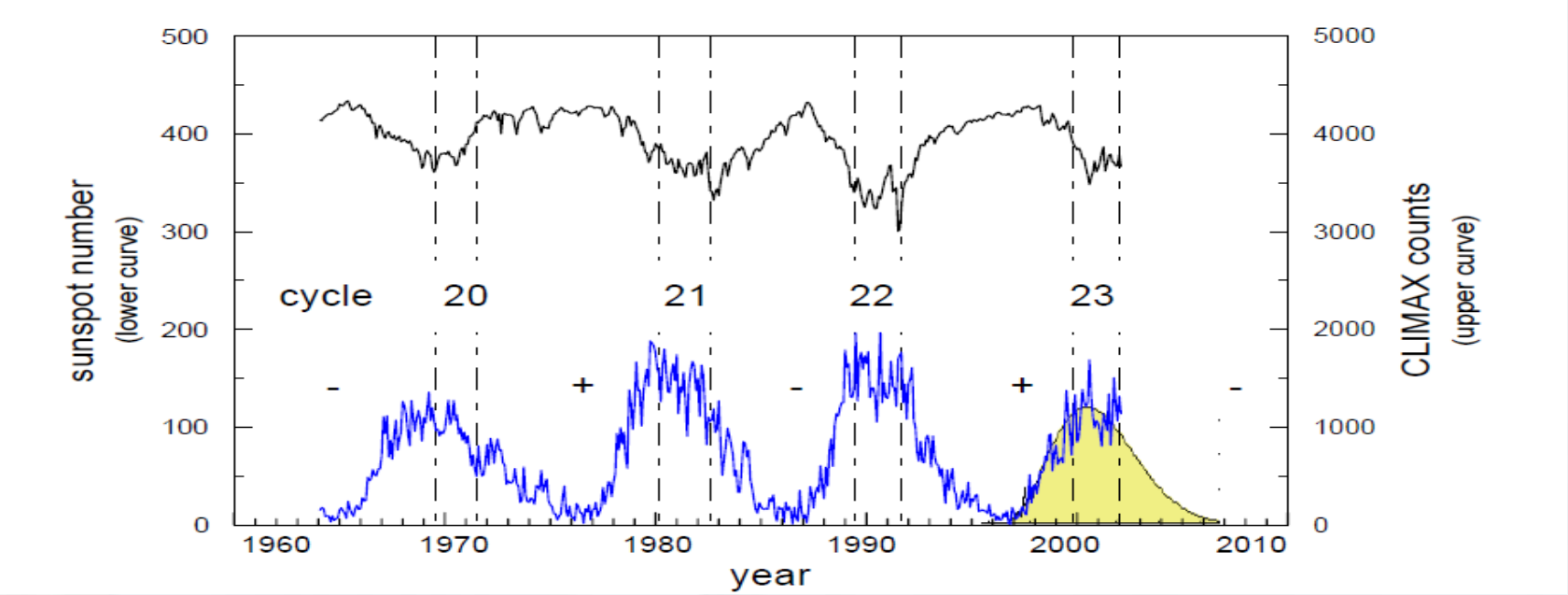


✓ Special thanks to KASI and KSWC for their support in this research

# INTRODUCTION

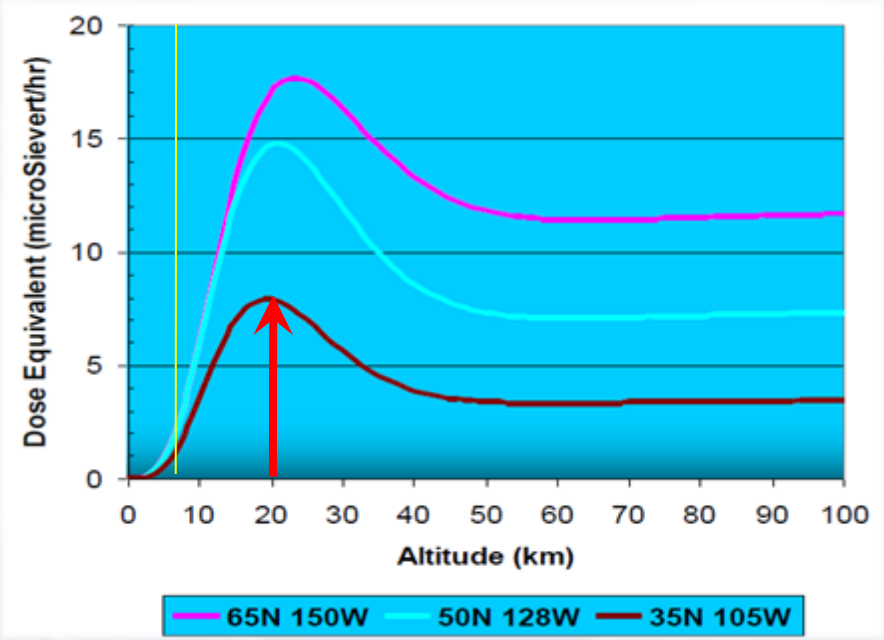
- ✓ All living creatures are exposed to radiation emitted from a variety of sources. The ionized particles enter the Earth from space as cosmic rays
- ✓ Cosmic radiation is in inverse relationship with solar activity

  : As solar activity goes down after its peak, a gradual increase of cosmic radiation is expected



# INTRODUCTION

- ✓ Most of the cosmic radiation is shielded by the atmosphere, so the radiation effect at the surface might be negligible
- ✓ Altitude over 8 km, cosmic radiation dramatically increases (Maximum exposure at Altitude 20 km)




(Turner, 2012)

# INTRODUCTION

✓Radiation exposure by occupation type (UNSCEAR 2000report)

| Source | Mining | Uses of radioactive | | Nuclear fuel cycle | Air travel(crew) |
|---|---|---|---|---|---|
| | | Indus | Medical | | |
| Effective dose(mSv/yr) | 1 ~ 5 | 0.5 | 0.3 | 1 ~ 2 | 3 |

✓ International regulations (ex. ICRP) are established to determine the criteria of the effective dose for the aircrew protection

| Division | ICRP | Japan/EU | Korea(Civil air) |
|---|---|---|---|
| Civilian | 1 mSv/yr | | |
| Air crew | 20 mSv/yr | 5~6 mSv/yr | 20 mSv/yr |

✓ In this research, objective analysis was done on the in-situ cosmic radiation measurements, which were collected by the spectrometers installed in the aircrafts flying over the Korean peninsula.

# Methodology

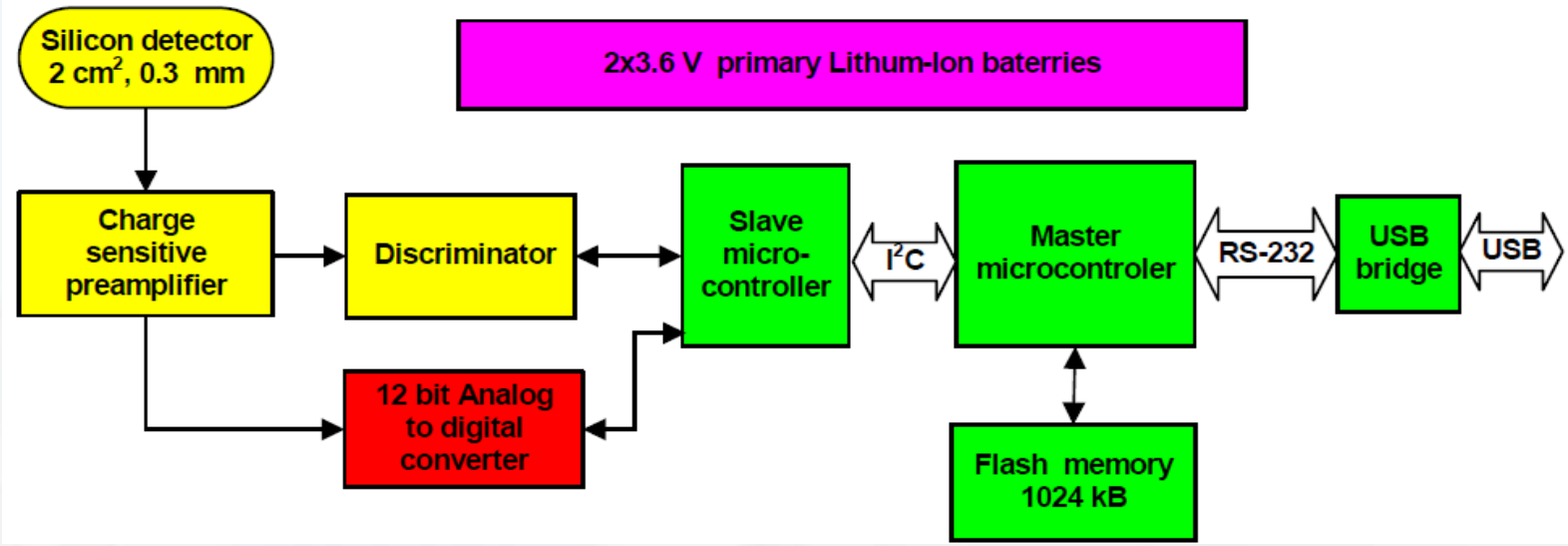
✓ Cosmic radiation measurement

- Period of measurement : Oct. 2012 ~ Jul.2014 (45 cases)
- Measurements and analysis were done on the data gathered from the spectrometer loaded on aircrafts during each mission flight
- Flight time : 1 ~ 9 hours day and night
- Flight altitude : Altitude according to aircraft types and missions

※ Each group of measurements were done with a fixed route and altitude

# Methodology

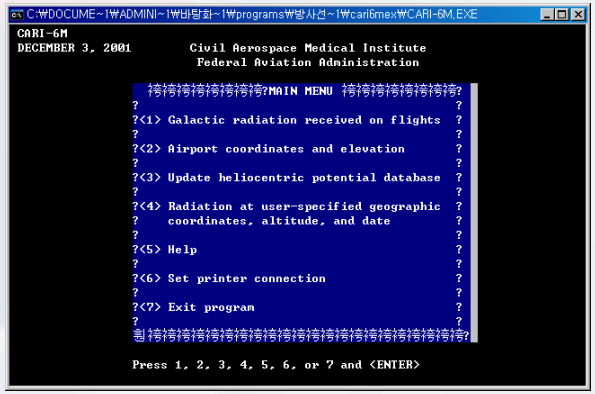
- ✓ Equipment : Liulin-6K spectrometer
- Manufactured by Bulgarian Solar-Terrestrial Influences Laboratory
- Silicon semiconductor detector
- Energy loss range : 0.04 ~ 20.83 MeV
- Certified as an avionics equipment

# Methodology

✓ Cosmic radiation exposure modeling program : CARI-6M

- Developed by CAMI(Civil Aerospace Medical Institute, FAA)
- Utilized to calculate the effective dose in civil airline flights
- Input data : departure, waypoint, destination, altitude(~ 87,000 ft)
- Calculated the effective dose using monthly HCP(Helio Centric Potential)
- Similar programs : EPCARD(German), JISCARD(Japan), PCaire(Canada), SIEVERT(France)



# Results of Measurement(2012)

✓ Result of measurement 2012 (18 cases)

| Altitude(ft) | Date | Total dose(μSv) | Flight time |
|---|---|---|---|
| 4,000 | 11/20 | 0.27 | 1h49m |
| 9,000 | 11/20 | 0.35 | 1h51m |
| 12,000 | 12/ 4 | 0.27 | 1h14m |
| 34,000 | 10/ 5 | 14.93 | 4h43m |
| 34,000 | 10/ 7 | 16.18 | 4h48m |
| 34,000 | 10/12 | 17.88 | 4h45m |
| 34,000 | 11/17 | 15.68 | 4h56m |
| 34,000 | 11/23 | 13.05 | 4h52m |
| 34,000 | 12/ 1 | 12.69 | 4h47m |
| 34,000 | 12/ 3 | 11.51 | 4h31m |
| 38,000 | 10/ 6 | 17.16 | 4h45m |
| 38,000 | 10/13 | 16.34 | 4h48m |
| 38,000 | 10/15 | 16.83 | 4h54m |
| 38,000 | 10/16 | 16.24 | 4h40m |
| 38,000 | 10/17 | 16.00 | 4h25m |
| 38,000 | 10/19 | 15.59 | 4h26m |
| 38,000 | 11/22 | 13.32 | 5h07m |
| 38,000 | 12/ 2 | 15.67 | 4h31m |

- Average time of cargo flight
  (Low Altitude) : 1h 38m
  Total dose : 0.30μSv (0.19μSv/h)
- Average time of mission flight
  (High Altitude) : 4h 44m
  Total dose : 15.27μSv (3.24μSv/h)
  10.2km Dose :14.56μSv (3.05μSv/h)
  11.4km Dose :15.89μSv (3.38μSv/h)

→ Large difference (tens of times) based on flight altitude

# Results of Measurement(2013)

✓ Result of measurement 2013 (9 cases)

| Altitude(ft) | Date | Total dose(μSv) | Flight time |
|---|---|---|---|
| 34,000 | 10/20 | 13.94 | 4h41m |
| 34,000 | 10/22 | 12.52 | 3h35m |
| 34,000 | 10/25 | 11.29 | 4h45m |
| 34,000 | 10/28 | 15.68 | 4h56m |
| 38,000 | 10/21 | 18.49 | 4h22m |
| 38,000 | 10/23 | 7.47 | 2h23m |
| 38,000 | 10/24 | 20.12 | 4h45m |
| 38,000 | 10/25 | 17.69 | 4h31m |
| 38,000 | 10/29 | 19.62 | 4h30m |

-Average time of mission flight
(High Altitude) : 4h 16m
Total dose : 15.20μSv (3.60μSv/h)
10.2km dose : 13.36μSv (2.72μSv/h)
11.4km dose : 16.68μSv (4.07μSv/h)
→ Missions at 38000 ft are more exposed to cosmic radiation compared to 34000 ft missions.

➢ High altitude flight pilots, who fly 300~400 hours annually, are exposed to cosmic radiation 0.97 ~ 1.44mSv per year.
→ Exceed civilian annual regulation of 1mSv

# Results of Measurement(2014)

✓ Result of measurement 2014 (18 cases)

| Altitude(ft) | Date | Total dose(μSv) | Flight time |
|---|---|---|---|
| 30,000 | 4/25 | 16.44 | 8h27m |
| 30,000 | 5/ 9 | 16.06 | 8h23m |
| 30,000 | 5/12 | 16.62 | 7h31m |
| 30,000 | 5/17 | 19.13 | 8h56m |
| 30,000 | 5/18 | 18.45 | 8h24m |
| 30,000 | 5/20 | 16.78 | 8h17m |
| 30,000 | 5/21 | 12.20 | 6h31m |
| 30,000 | 5/27 | 18.94 | 9h13m |
| 30,000 | 6/10 | 16.82 | 7h22m |
| 30,000 | 6/11 | 15.38 | 7h49m |
| 30,000 | 6/13 | 8.18 | 3h55m |
| 30,000 | 6/16 | 17.51 | 7h02m |
| 30,000 | 6/20 | 16.65 | 8h02m |
| 30,000 | 6/25 | 20.66 | 9h03m |
| 30,000 | 6/26 | 11.65 | 5h05m |
| 30,000 | 7/ 3 | 16.68 | 8h12m |
| 30,000 | 7/14 | 10.79 | 5h50m |
| 30,000 | 7/29 | 16.33 | 7h58m |
| 30,000 | 8/5 | 12.18 | 6h00m |
| 30,000 | 8/21 | 16.53 | 7h59m |
| 30,000 | 8/27 | 20.44 | 7h57m |
| 30,000 | 9/24 | 15.67 | 7h59m |
| 30,000 | 9/26 | 16.04 | 7h58m |
| 30,000 | 9/30 | 14.31 | 8h00m |

- Average time of mission flight (High Altitude) : 7h 33m

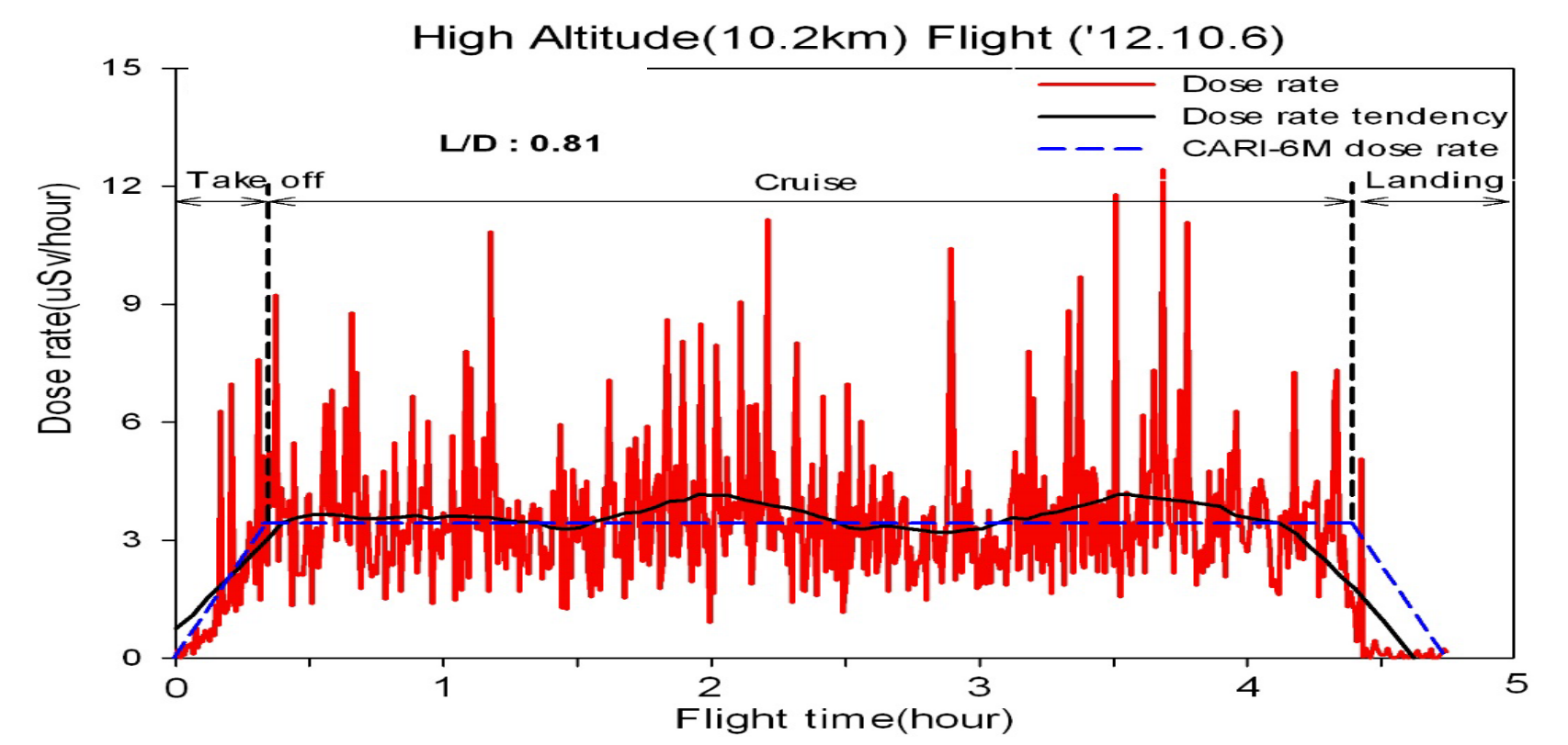
Average dose: 15.85μSv (2.10μSv/h)

→ Dose rate is sensitive to altitude change

※ Considering long annual flight time (about 1000 hours), crews could be exposed to cosmic radiation up to 2mSv

# Results of Measurement

✓ Time series of the cosmic radiation (10.2 km)

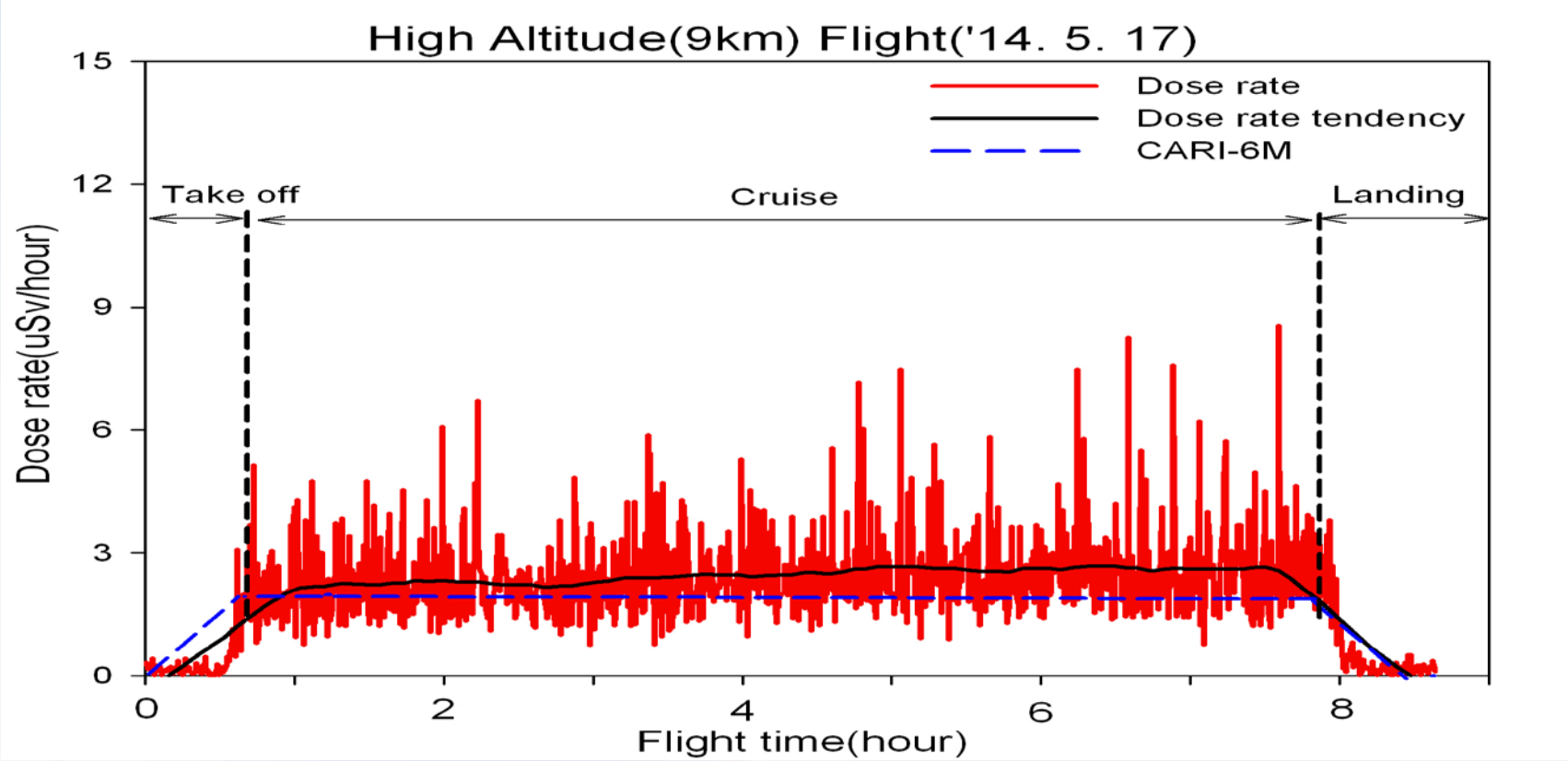



➢ High altitude flight crew cosmic radiation exposure

→ The effective dose and the dose rate change with each flight phase (take-off, cruise, landing). During take-off and landing, the change is dramatic

# Results of Measurement

✓ Time series of the cosmic radiation (9 km)

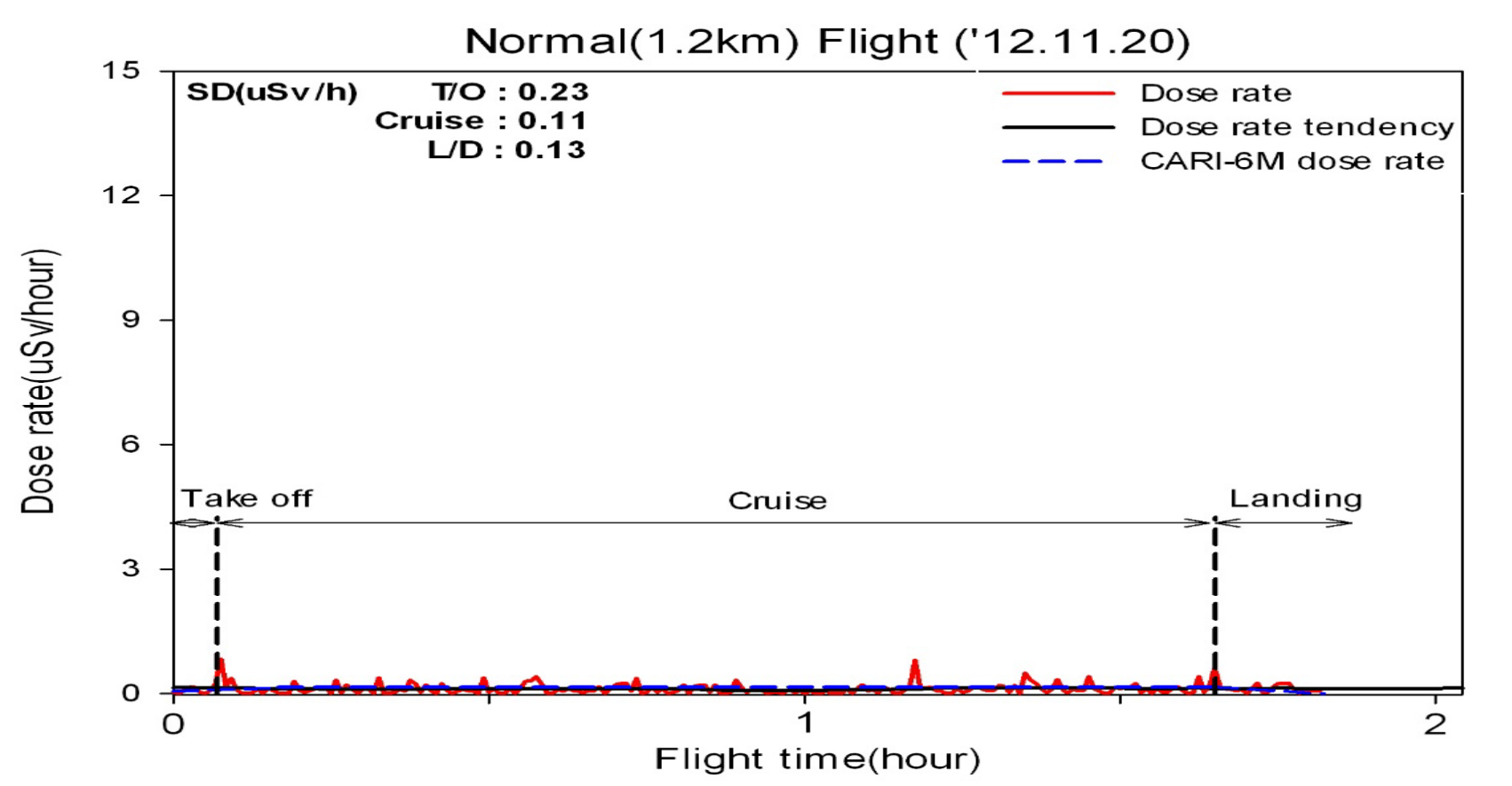



➢ High altitude flight crew cosmic radiation exposure

→ The effective dose and the dose rate change with each flight phase (take-off, cruise, landing). During take-off and landing, the change is dramatic

# Results of Measurement

✓ Time series of the cosmic radiation(1.2km )

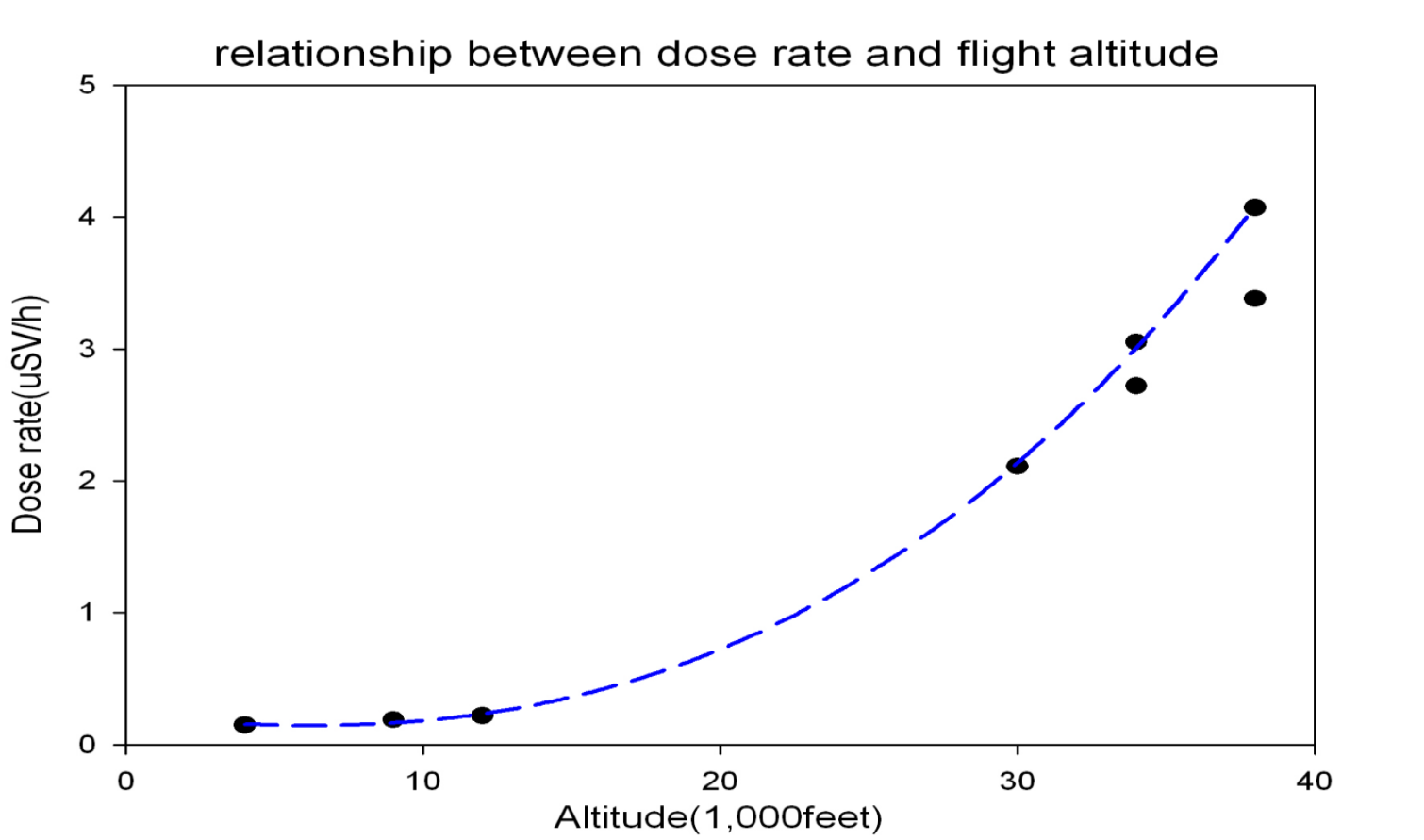



➢ Cosmic radiation exposure of cargo crew

→ Almost the same as ground level

# Results of Measurement

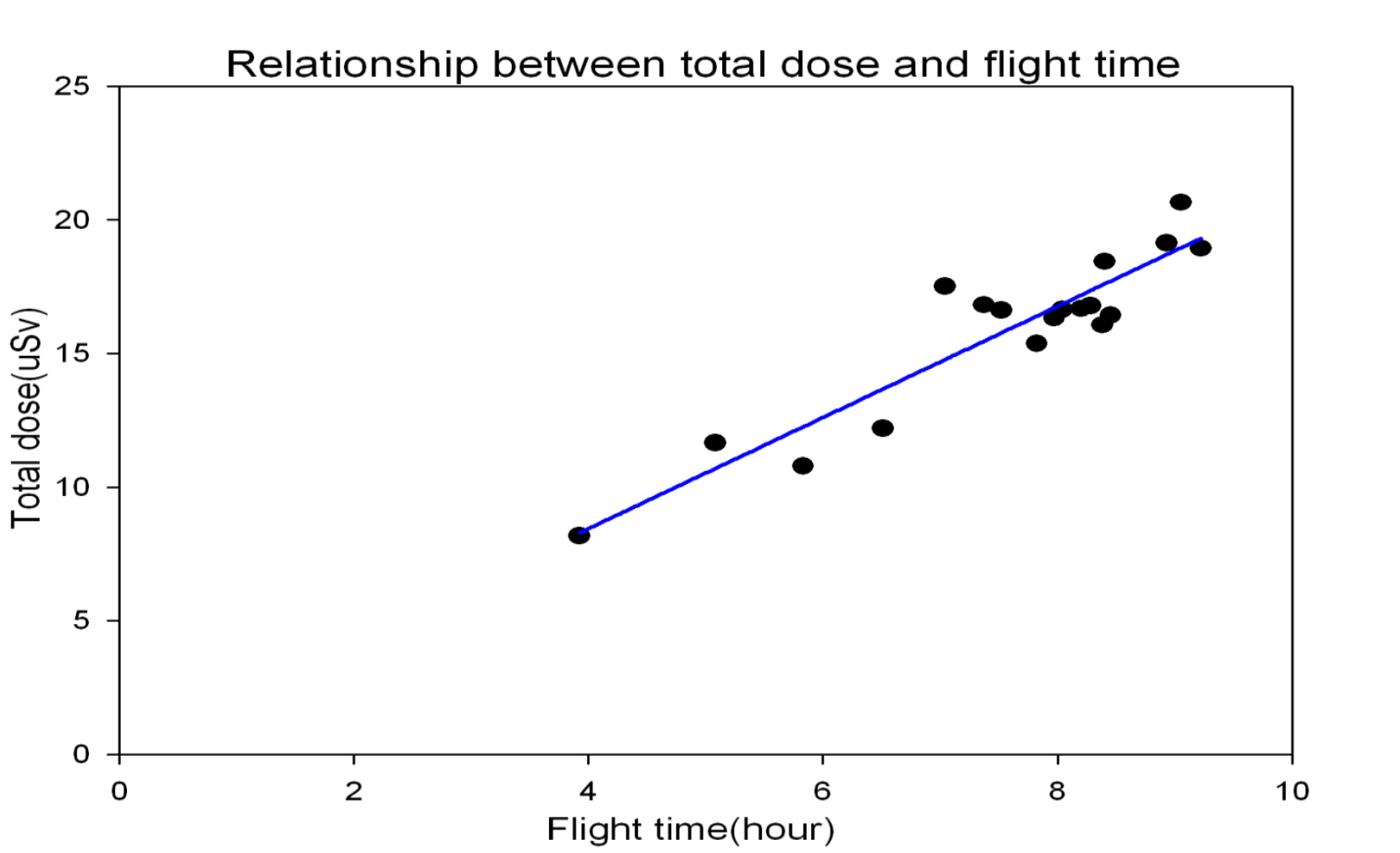
- ✓ Relationship between dose rate and flight altitude




- ➢ The effective dose has positive correlation with altitude

# Results of Measurement

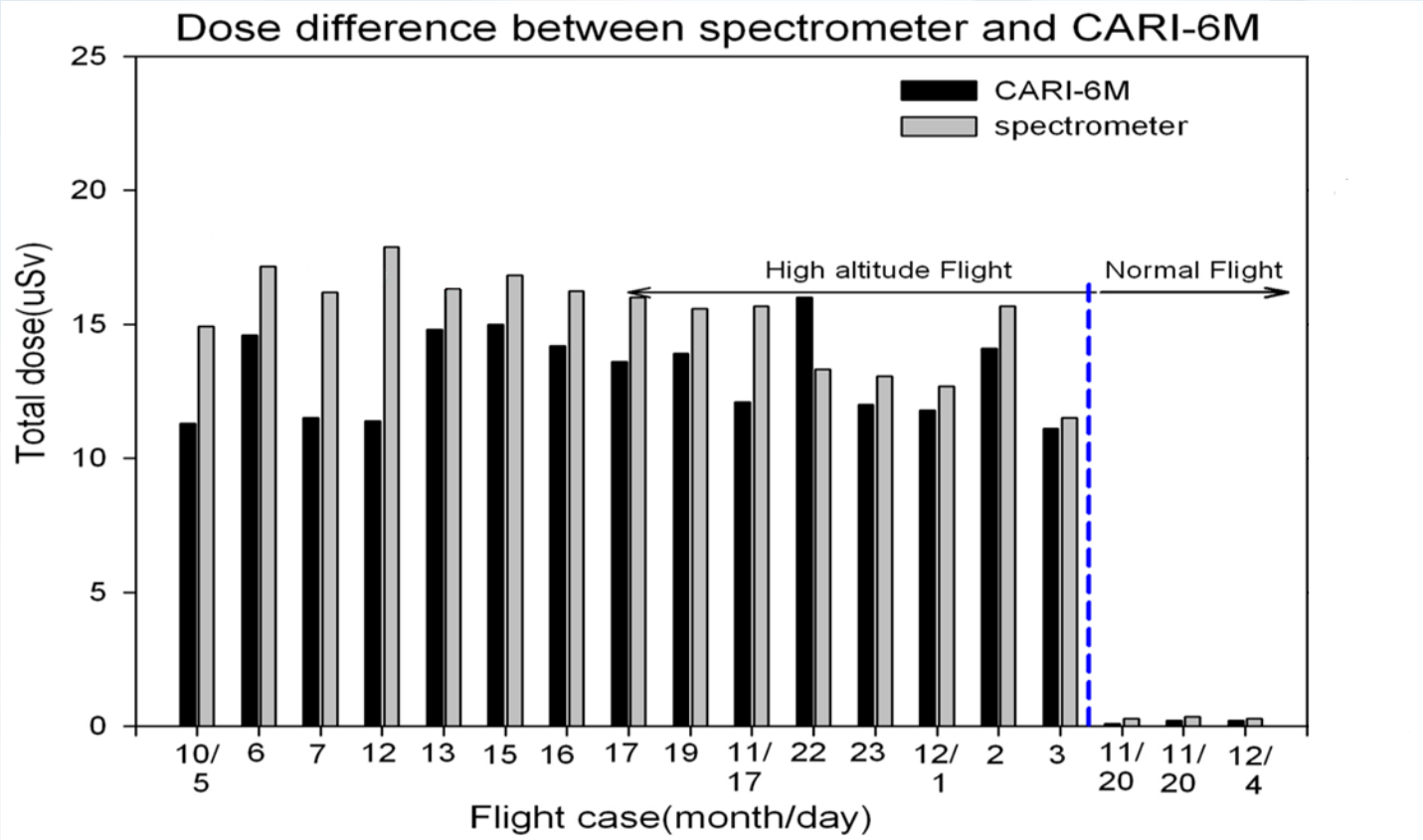
- ✓ Relationship between total dose and flight time (9 km)




- ➢ The effective dose has positive correlation with time

# Results of Measurement

✓ Dose difference between spectrometer and CARI-6M (2012)

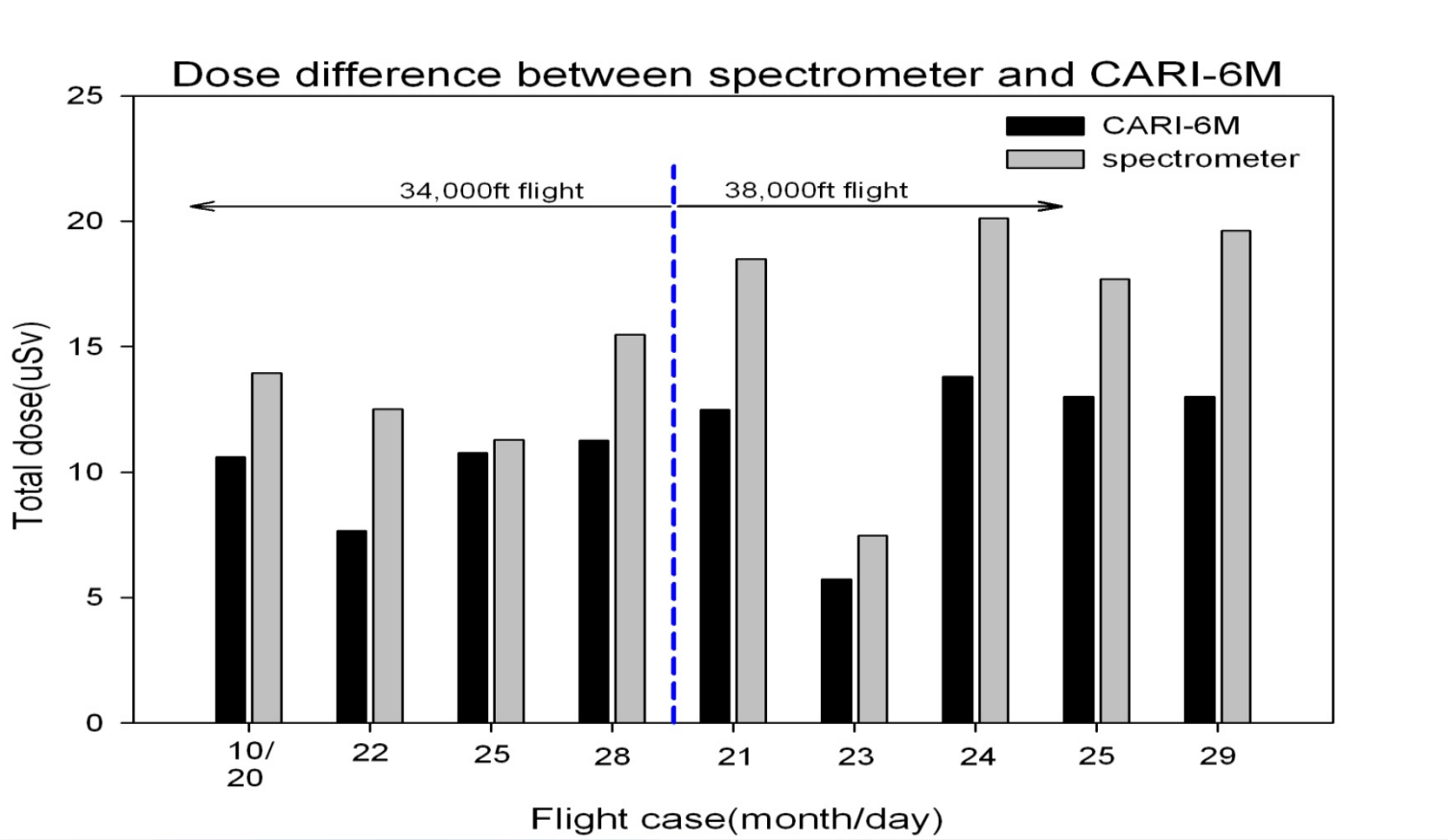



✓ The distribution of measured data is similar to simulated data

✓ During high-altitude flights in 2012, measured data was higher than simulated data in all except one flight

# Results of Measurement

✓ Dose difference between spectrometer and CARI-6M (2013)

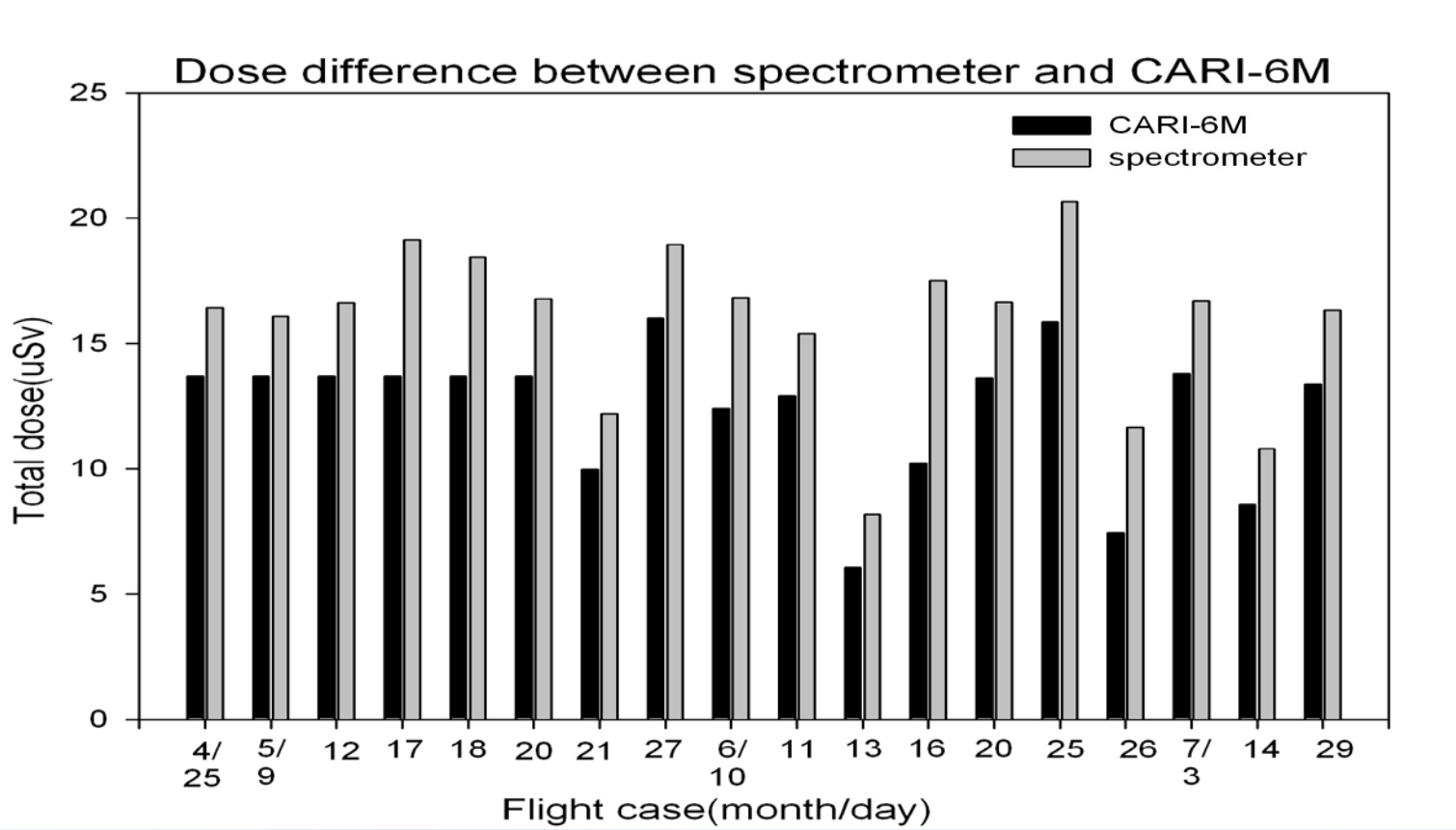



✓ The distribution of measured data is similar to simulated data

✓ During high-altitude flights in 2013, measured data was always higher than simulated data.

# Results of Measurement

✓ Dose difference between spectrometer and CARI-6M (2014)




✓ The distribution of measured data is similar to simulated data

✓ During high-altitude flights in 2014, measured data was always higher than simulated data.

# Summary

This research showed us that;

- ✓ above 9 km, the effective dose increases drastically corresponding to flight altitude and flight time
- ✓ continuous monitoring, quantitative data analysis, and an effective dose management plan for aircrews are required

✓ Thank you for listening