Radiation Dosimetry Experiment (RaD-X): High-Altitude Balloon Flight Mission for Improving the NAIRAS Model

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**NAIRAS Model**
- NASA Nowcast of Atmospheric Ionizing Radiation for Aviation Safety (NAIRAS) Model
  - Prototype operational model
  - Running in real-time at the NASA Langley Research Center since April 2011

**Distinguishing Features**
- Real-time physics-based, deterministic, global model
- Real-time inclusion of both galactic cosmic radiation (GCR) and solar energetic particle (SEP) radiation
- Real-time solar-magneto-spheric effects on geospace radiation environment
- Real-time meteorological data (NCEP/GFS)

**Upper/Left:** Climatology of zonal-average GCR effective (full-body average) dose rates at various altitudes and flight levels (FL)
  - Solar Minimum (solid green line); Solar Maximum (solid blue line)
  - The dashed lines: +/- 1-standard deviation

**Upper/Right:** Climatology of GCR effective dose rates as a function of vertical geomagnetic cutoff rigidity at various altitudes and flight levels (FL). Line style/color same as upper/left figure

**Adjacent Figure:** Dosimetric flight measurements from Dusseldorf, Germany (DUS) to Mauritius (MRU) on 13-14 February 2008 (courtesy of Matthias Meier, DLR)
- 1 min TEPC ambient dose equivalent rate [uGy/hr, red line]
- Ambient dose equivalent operational surrogate for effective dose
- 1 min TEPC tissue absorbed dose rate [uSy/hr, blue line]
- 1 min Liulin silicon absorbed dose rate [uSy/hr, green line]

**Upper/Left:** TEPC/NAIRAS comparisons of 1-hour averaged silicon absorbed dose rates for DUS-MRU 13-14 February 2008 flight
- NAIRAS underestimates TEPC by about 50%
- These results consistent with comparisons with ICRU Report 84 reference aircraft measurements (Mertens et al., 2013)

**Upper/Right:** Liulin/NAIRAS comparisons of 1-hour averaged silicon absorbed dose rates for DUS-MRU 13-14 February 2008 flight
- NAIRAS underestimates Liulin by about 70%

**Conclusions**
- Suggest largest NAIRAS uncertainty in charged particle source/transport/interactions
- Measurements at flight altitudes alone cannot unambiguously identify source of NAIRAS model uncertainty

**RaD-X Science**

**Goals and Objectives**
- **Goal 1:** Improve NAIRAS model by characterizing energy deposition of cosmic ray primary (CR) particles
  - **Objective 1:** Measure dosimetric quantities in the upper atmosphere above the Pfotzer maximum to isolate CR primaries
  - **Objective 2:** Utilize dosimeters that can isolate proton and heavy-ion CR primaries and atmospheric neutrons
- **Goal 2:** Identify low-cost atmospheric radiation dose measurement solutions for global, continuous monitoring
  - **Objective 3:** Characterize the relationship between silicon-based dosimetric measurements and radiobiological response

**High-Altitude Measurements**
Taking data at high altitude above the Pfotzer maximum provides a direct measurement of CR primaries, permitting the separation of discrepancies due to source uncertainties from discrepancies caused by the ensemble of complex physical processes at aircraft flight altitudes

**Instrument Selection**

The choice of dosimeters was motivated by:
- Ability to separate CR primary protons and heavy-ions and atmospheric neutrons by combining measurements at two float altitude regions (Region-A and Region-B shown below)
- Viable low-cost dosimeters for continuous, global monitoring of radiobiological response (direct measurement or empirical fit)

**TEPC:** Industry standard microdosimeter provides radiation protection (operational) dose measurement, which is defined as ambient dose equivalent [ICRU, 2010; ISO, 2012]

**Liulin:** Silicon-based LET spectrometer that permits identification of protons at Region-A and separation of heavy-ion contributions at Region-B

**TID:** Teledyne total ionizing dose (TID) detector that is mostly sensitive to charged particles at RaD-X altitudes. Viable silicon-based dosimeter for continuous, global radiation monitoring. Requires empirical fit to TEPC ambient dose equivalent to characterize radiobiological response.

**RaySure:** Viable silicon-based microdosimeter “emulator” which is easy to manufacture, internal calibration directly computes ambient dose equivalent.

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**RaD-X Mission**

**Mission and Instrument Parameters**
- **Platform:** High- Altitude Balloon
- **Launch Site:** Fort Sumner, NM
- **Mission Duration:** 24-hours
- **Temporal Sampling:** 1-5 minutes
- **Launch Readiness Date:** September 2015
- **Instruments:** (1) TEPC, (2) Teledyne TID dosimeter, (3) Liulin LET Spectrometer, and (4) RaySure microdosimeter emulator
- **Measurement Uncertainty:** < 30%
- **Instrument TRL:** All components TRL 6 or higher

**Concept of Operation**

**Science Payload and Gondola**

**Milestones and Science Activities**
- **Project Milestones**
  - Selection Conference (08/20/2013)
  - Kickoff (01/31/2013)
  - SRR: Systems Requirements Review (02/19/2014)
- **Near-Term Science Activities**
  - Modeling instrument and radiation shielding environment (05/2014)
  - PDR: Preliminary Design Review (05/2014)
  - Dosimeter Beam Test and Calibration (08/2014)