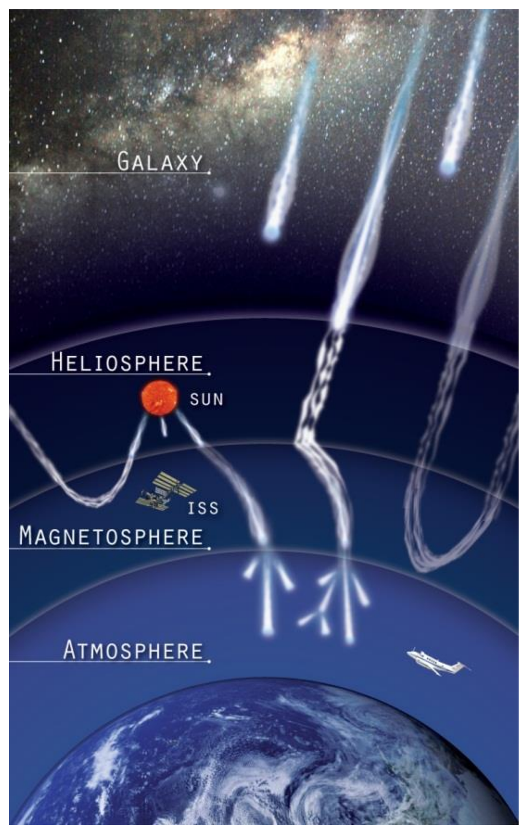
Radiation Dosimetry Experiment (RaD-X): High-Altitude Balloon Flight Mission for Improving the NAIRAS Model

Christopher J. Mertens[1], Erica J. Alston[1], Tore Straume[2], Brad Gersey[3], Terry C. Lusby[2], Ryan B. Norman[1], Guillaume P. Gronoff[4], W. Kent Tobiska[5], and Rick Wilkins[3]

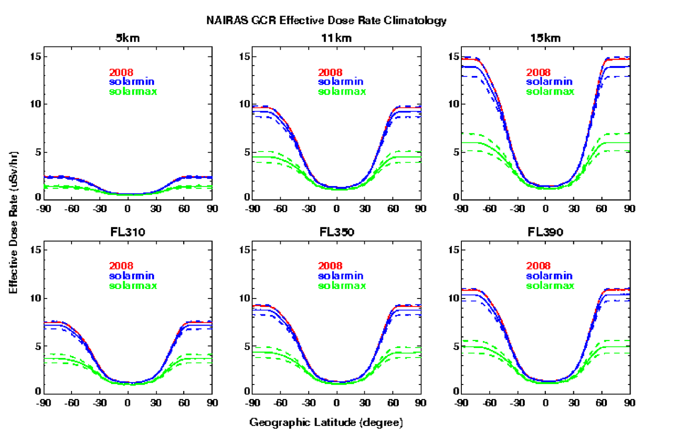
[1]NASA Langley Research Center, [2]NASA Ames Research Center, [3]Prairie View A& M University, [4]Science Systems and Applications, [5]Space Environment Technologies

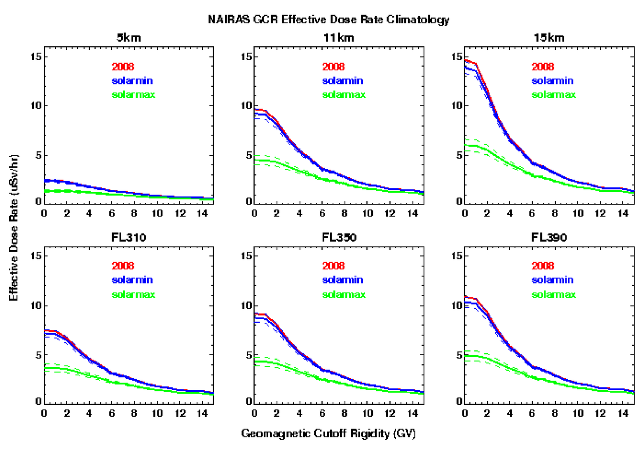
NAIRAS Model

- **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-magnetospheric effects on geospace radiation environment
  - Real-time meteorological data (NCEP/GFS)



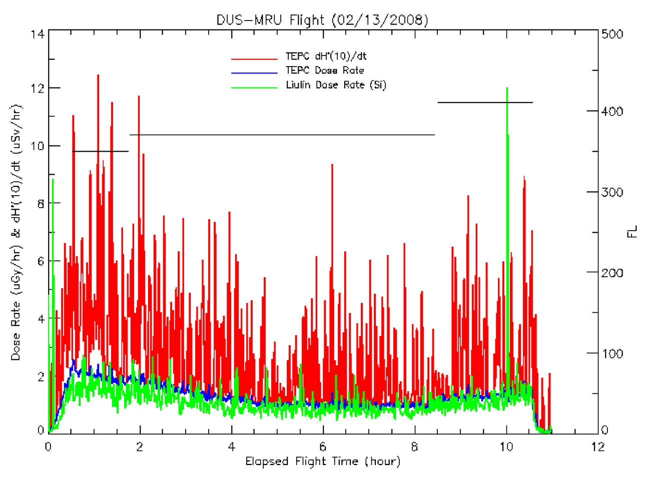
Public Web site: http://sol.spacenvironment.net/~nairas/ (or google NAIRAS)

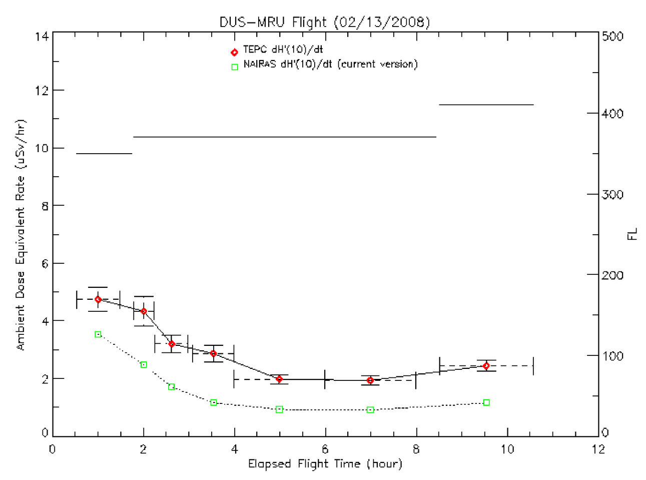


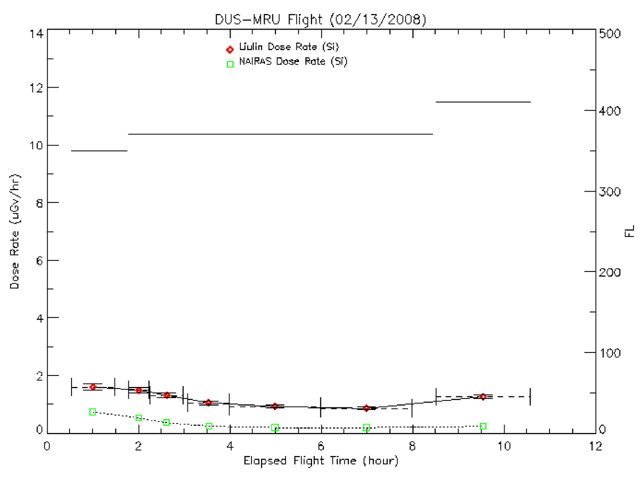


- **Upper/Left:** Climatology of zonal-average GCR effective (full-body average) dose rates at various altitudes and flight levels (FL)
  - Solar Minimum (solid green line); Solar Maximum (solid blue line)
  - The dashed lines: +/- 1-standard deviation
- **Upper/Right:** Climatology of GCR effective 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 (uSy/hr; red line)
    - Ambient dose equivalent operational surrogate for effective dose
  - 1 min TEPC tissue absorbed dose rate (uGy/hr; blue line)
  - 1 min Liulin silicon absorbed dose rate (uGy/hr; green line)







- **Upper/Left:** TEPC/NAIRAS comparisons of 1-hour averaged ambient dose equivalent 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

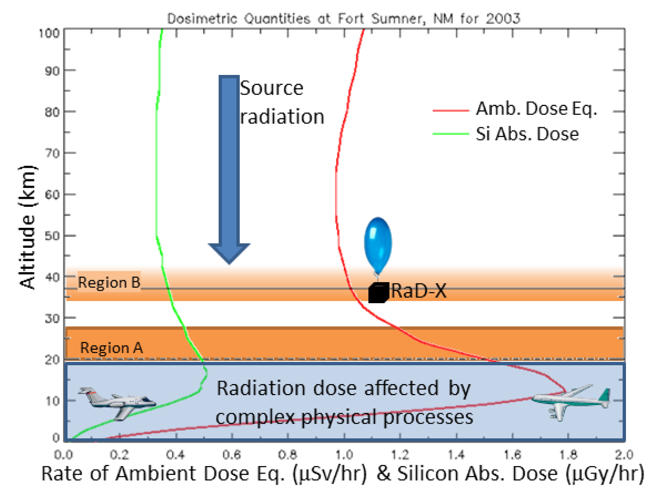
Goals and Objectives

- **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

- The radiation environment in the upper atmosphere above the Pfotzer maximum is a large source of uncertainty for radiation exposure at aircraft flight altitudes [*Lindborg et al., 2004*]
- Model/measurement comparisons at aircraft altitudes point out discrepancies, but do little to reveal a causal source of discrepancy due to variation in composition and energy of the radiation environment with atmospheric depth

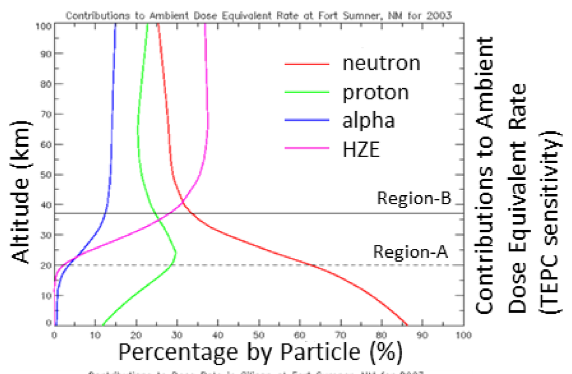


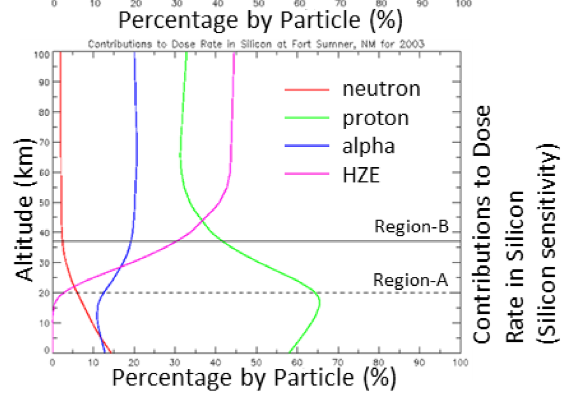
Instrument Selection

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.





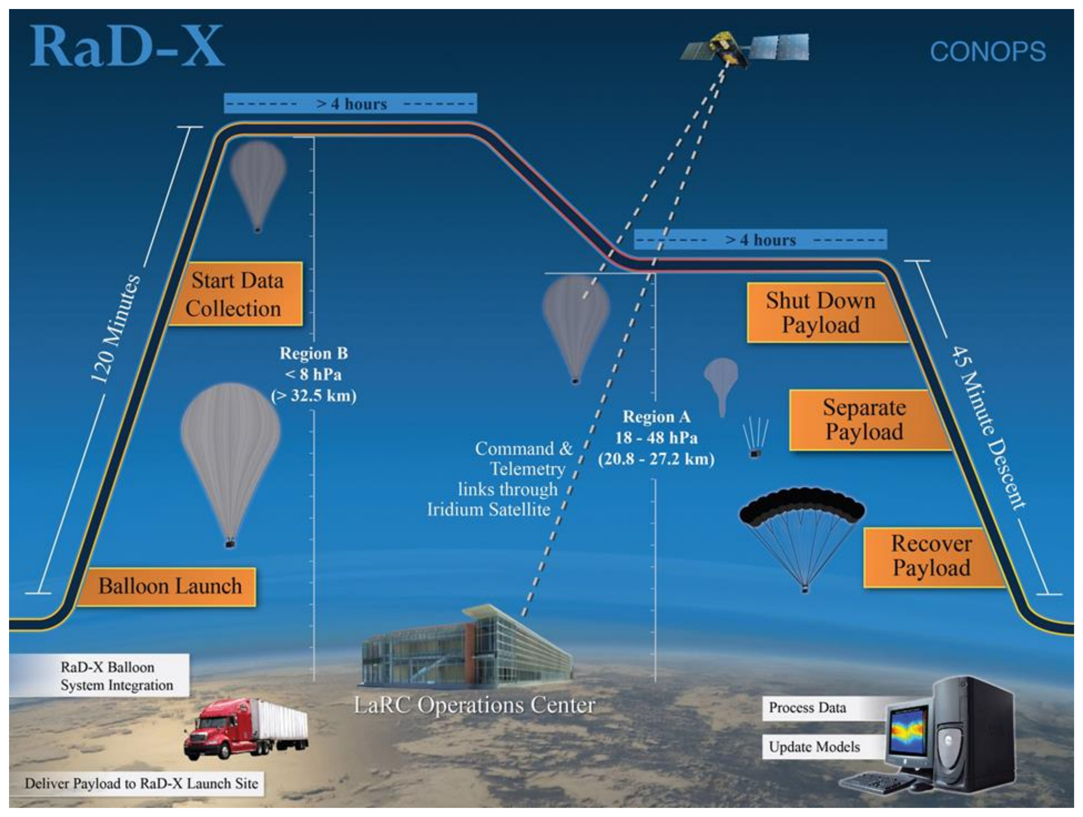
POC: Christopher.J.Mertens@nasa.gov

RaD-X Mission

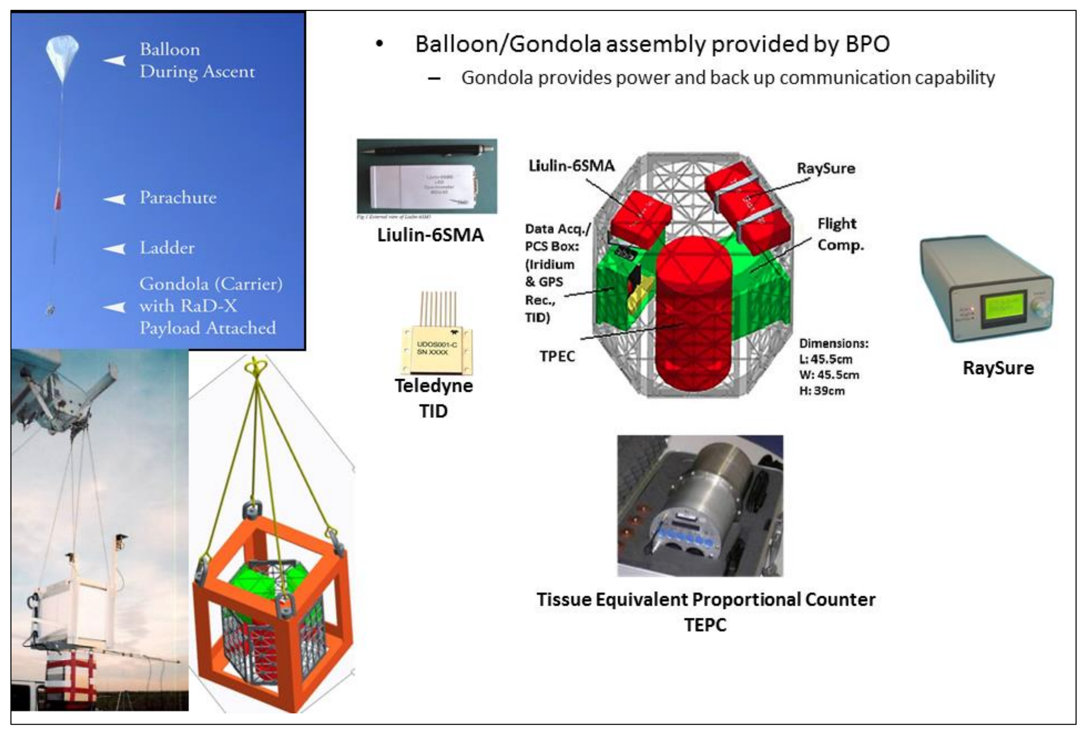
Mission and Instrument Parameters

- **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 (10/31/2013)
  - 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)