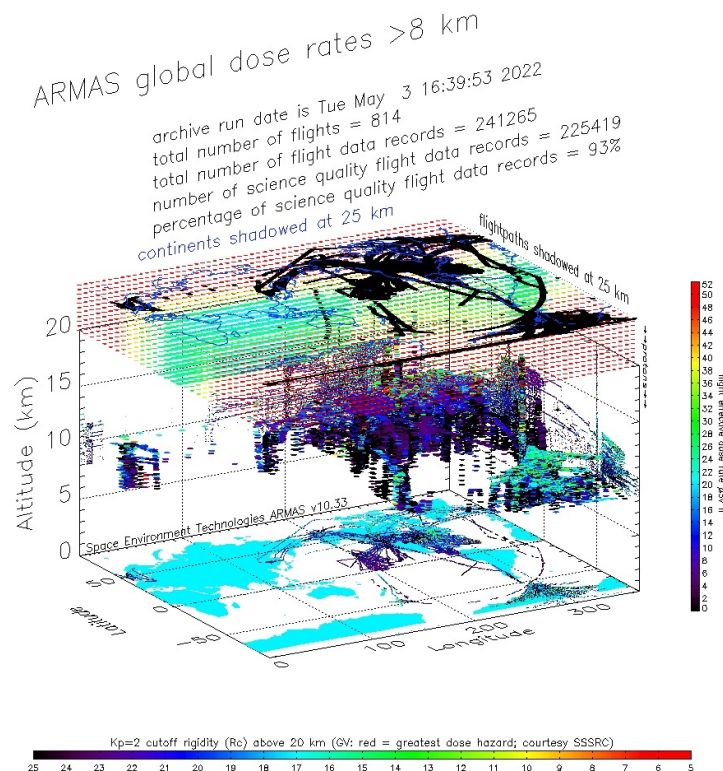




Characterizing the Global Aviation Radiation Environment based on Model and Measurement Databases

BENCHMARK RADIATION DATASET:
>1 million 10-second ARMAS global
data records over 10 years

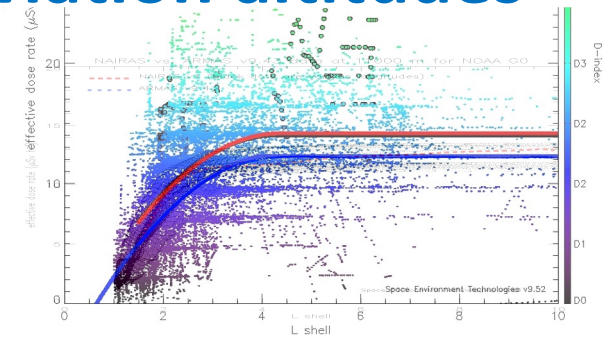


W. Kent Tobiska
Space Environment Technologies



Background: Space weather creates a dynamic radiation environment at aviation altitudes

Observed dose rate vs. L-shell
Modeled GCR dose rate vs. L-shell

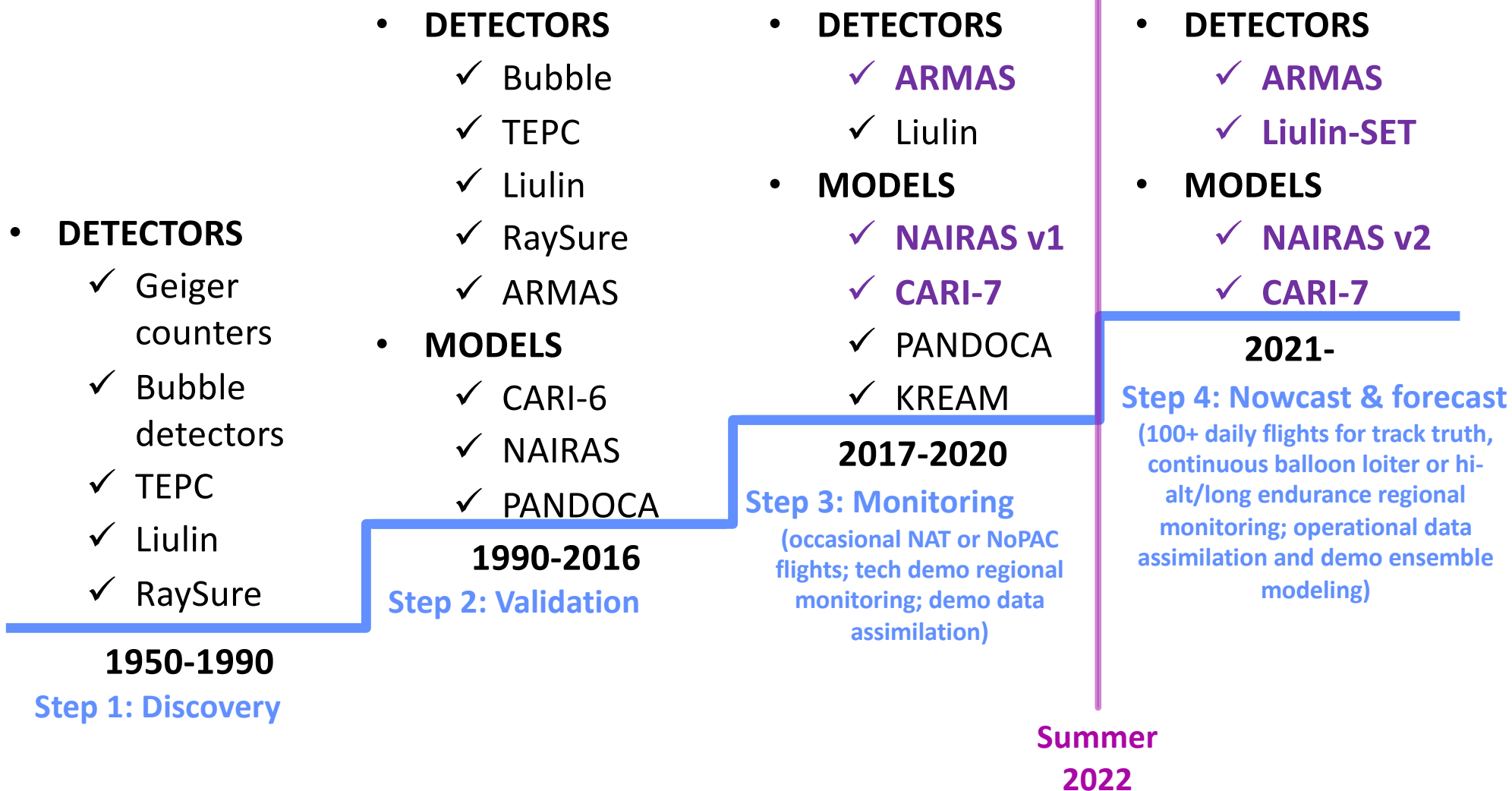


Radiation sources above 8 km

- ✓ **Known global phenomenon:** GCRs create a career health issue and source for avionics SEUs
- ✓ **higher latitude phenomenon**
 - ✓ **Known extended major events:** SEPs can affect fleet operations and aircrew/passenger monthly limits
 - **Research area short-term minor events:** secondary radiation from precipitating radiation belt energetic particles are an incremental career health issue



Where are we today? Progress towards aviation radiation nowcast & forecast





ARMAS radiation weather monitoring from the surface to LEO

Activity	Support	Project
Science	NASA LWS	✓ RADIAN – data assimilation of ARMAS into NAIRAS; implemented
	SET IR&D	✓ CARI-7 verification; implemented
	NASA R2O2R	● ARMAS-ML: Machine-learning w/ data
Data collection	NASA SBIR	✓ ARMAS FM5, γ -ray spectrometer, on WVE 30-day Stratollite balloon
	USAF SBIR	✓ ARMAS/ARGOS FM5 20 km, 1 year
	NASA SBIR	✓ SWAP-E/ARMAS FM8B cubesats (3)
	NASA SBIR	✓ iSSI/ARMAS FM9+Luilin-SET on ISS
Instruments	NASA SBIR	○ OPSRAD LET detector



814 ARMAS Flights from 0-550 km in 2013–2022

✓ Agency and Commercial Aircraft flying ARMAS

- ✓ **AFRC:** DC-8 (a), ER-2 (d), G-III, SOFIA (B747)
- ✓ **NOAA:** G-IV (b)
- ✓ **NSF:** G-V (c)
- ✓ **FAA:** Bombardier Global 5000
- ✓ **DoE:** B350
- ✓ **Commercial:**
 - Boeing 737, 747, 757, and 777
 - Airbus 319 and 320
 - Bombardier Q200
 - CRJ 200, 700; Embraer 175

✓ Balloons

- ✓ **World View Enterprises:** Stratollite (f)

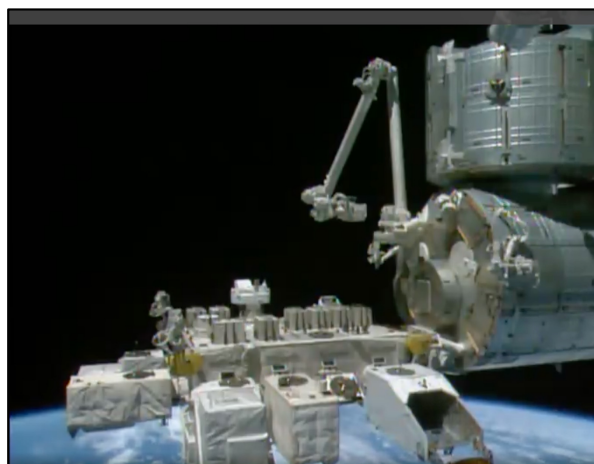
✓ NASA space stations

- ✓ ISS (Low Earth Orbit)
- Gateway (Lunar Orbit)

✓ Proprietary vehicles

- ✓ **Perlan** Stratospheric glider (e)
- ✓ **Virgin Galactic** SS2 and WK2 (g)
- ✓ **Blue Origin** New Shepard (h)
- ✓ **SpaceX/NSL** Transporter-2/TAGSAT-2
- Lunar lander

- ✓ Flown
- In progress
- Potential

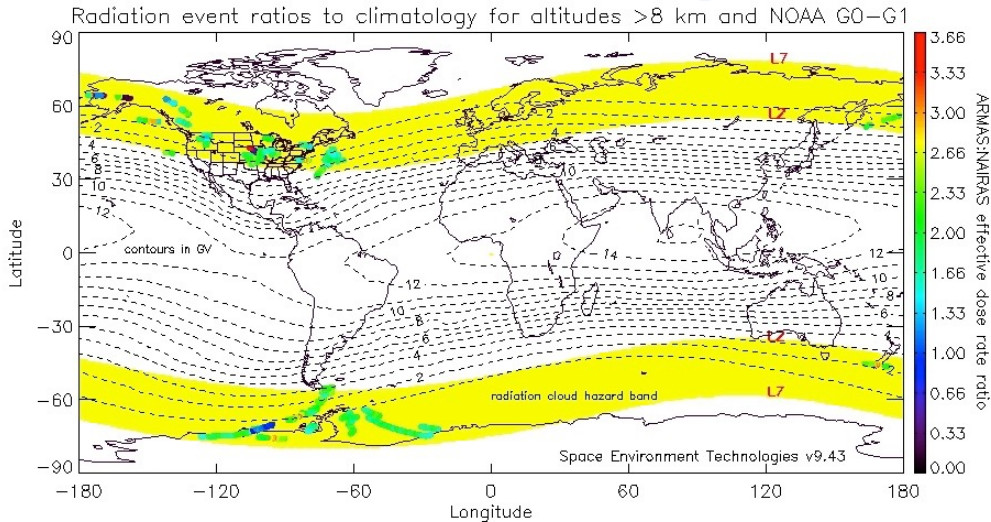


1 million 10-s data records and counting

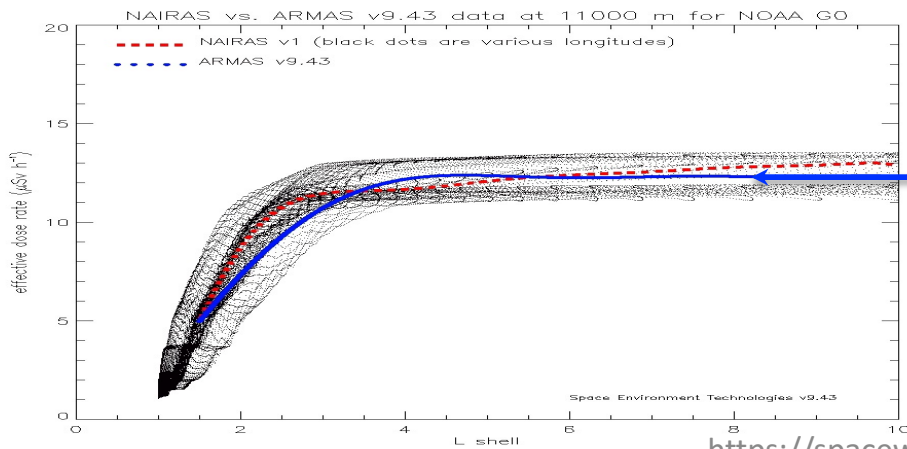
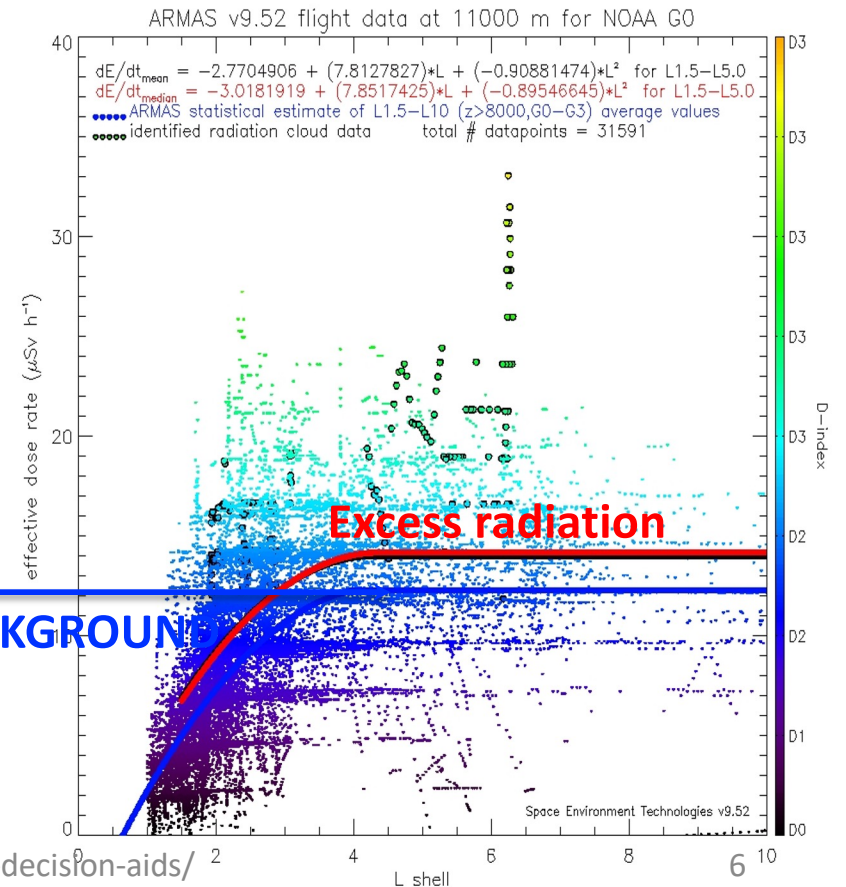


Science question: why do the dose rates at $2 < L < 7$ and ≥ 11 km during geomagnetic quiet conditions rise above GCR background?

GREEN dots = 2 times background



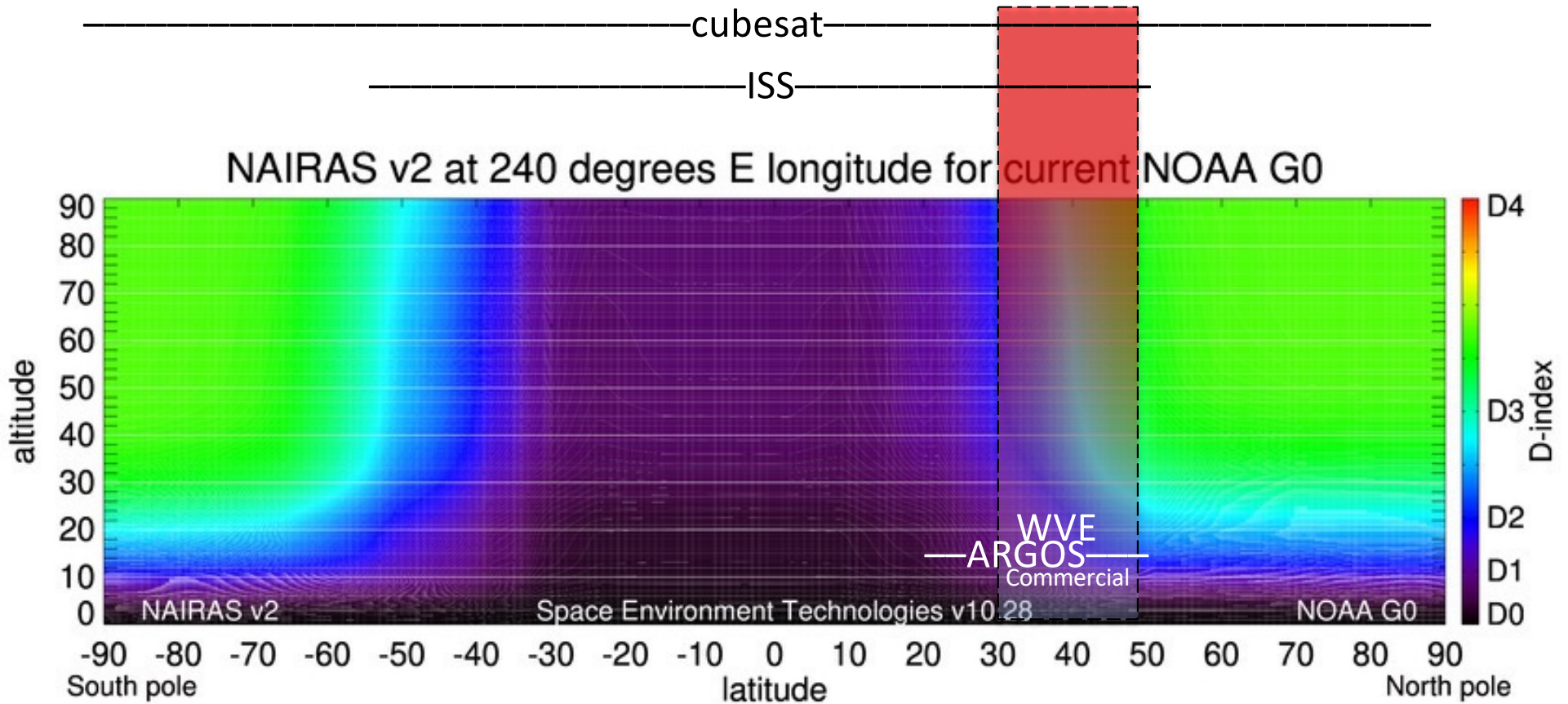
ARMAS GCR + REP MEASURED DOSE



<https://spacewx.com/radiation-decision-aids/>



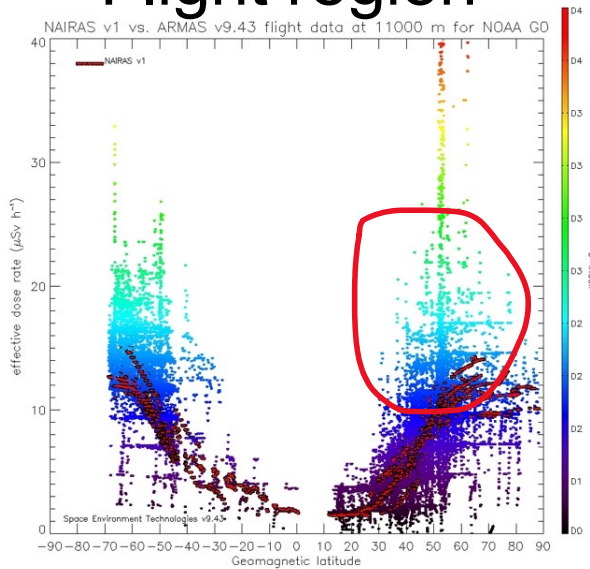
ARMAS Dual Monitor will measure first ever radiation column in 2022





ARMAS Dual Monitor WVE balloon will demonstrate 24/7 operations for 30-days and will address science

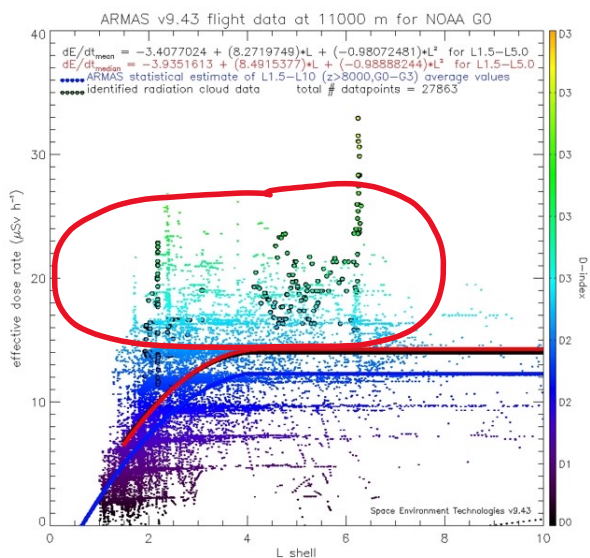
Flight region



Instrumentation

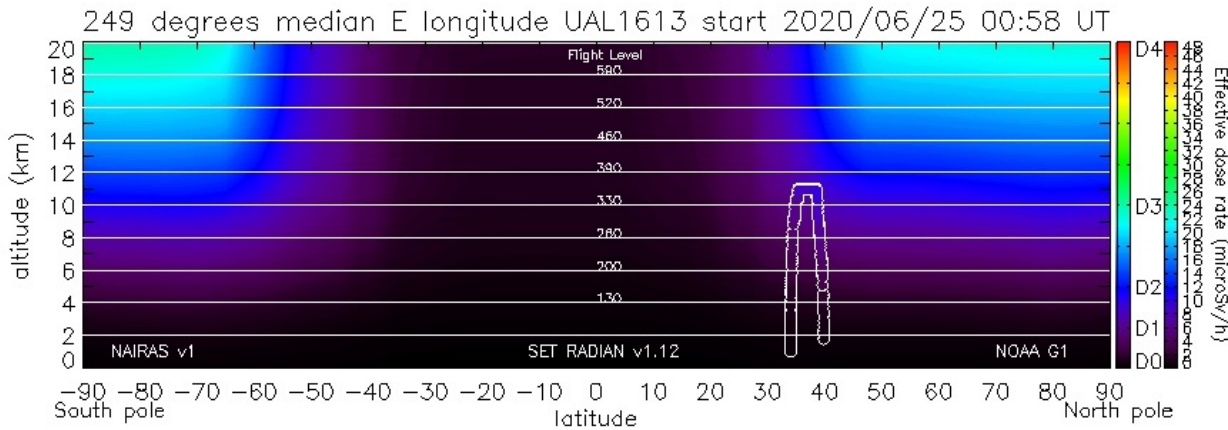


Flight demo

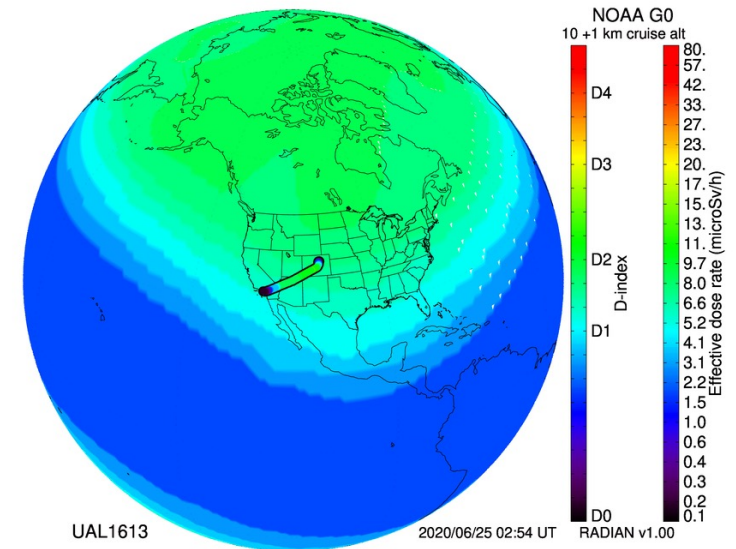
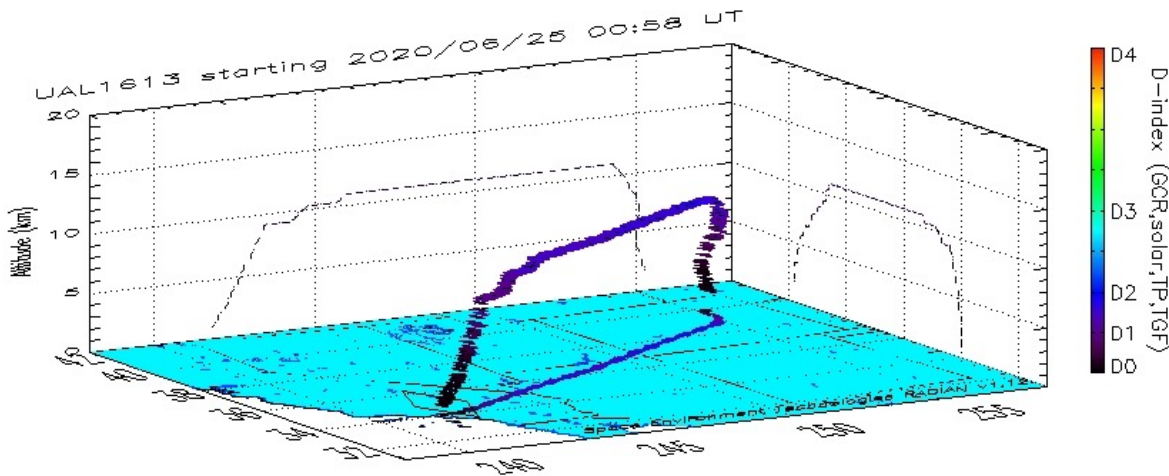




ARMAS measurements integrated with NAIRAS v2 create the RADIAN data cube using FM1-FM7 with a legacy in 814 flights



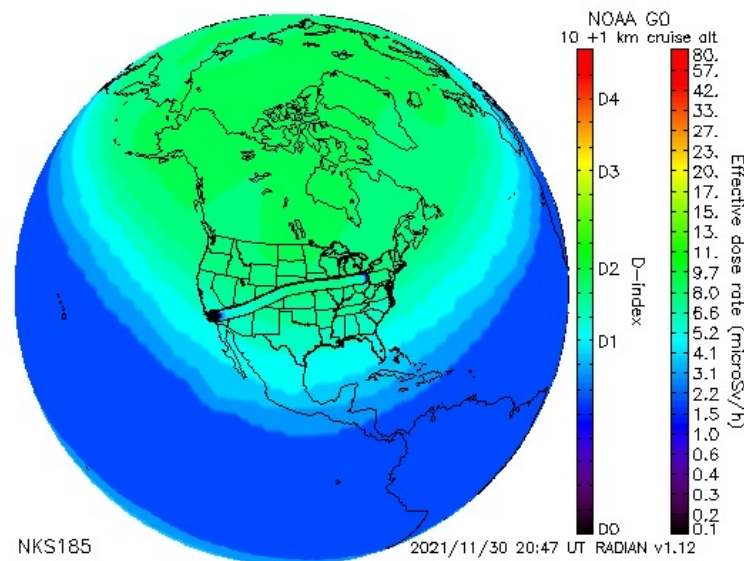
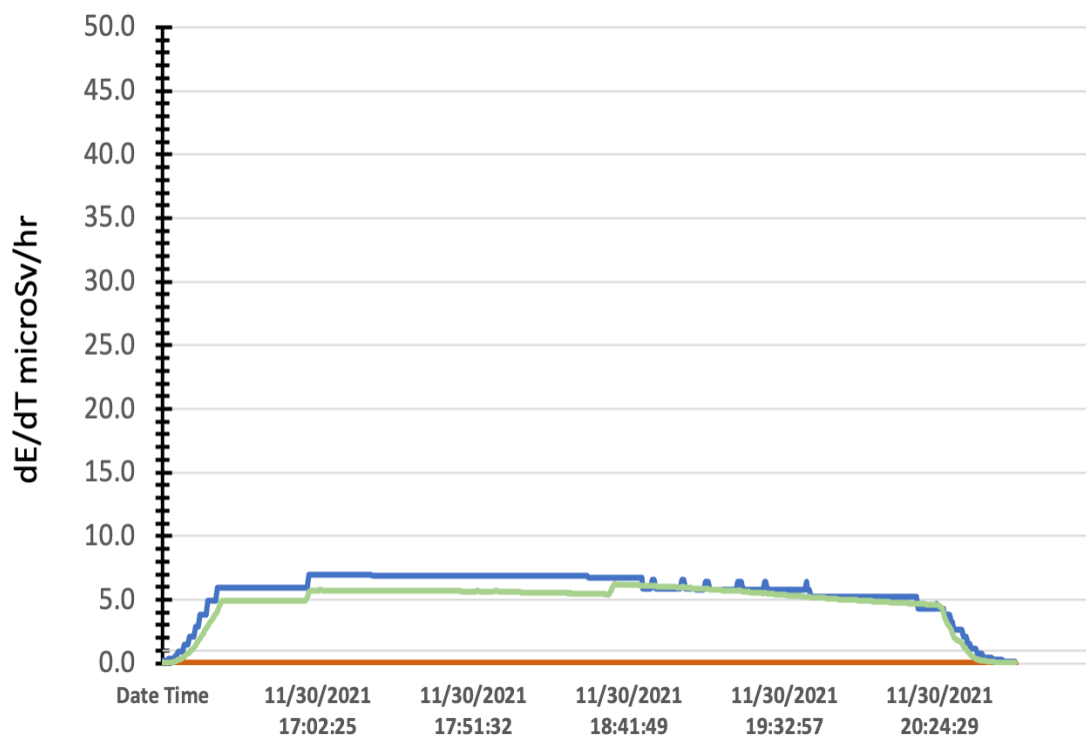
RADIAN now provides flight tracks for any aircraft in the world (via ARMAS iOS app)





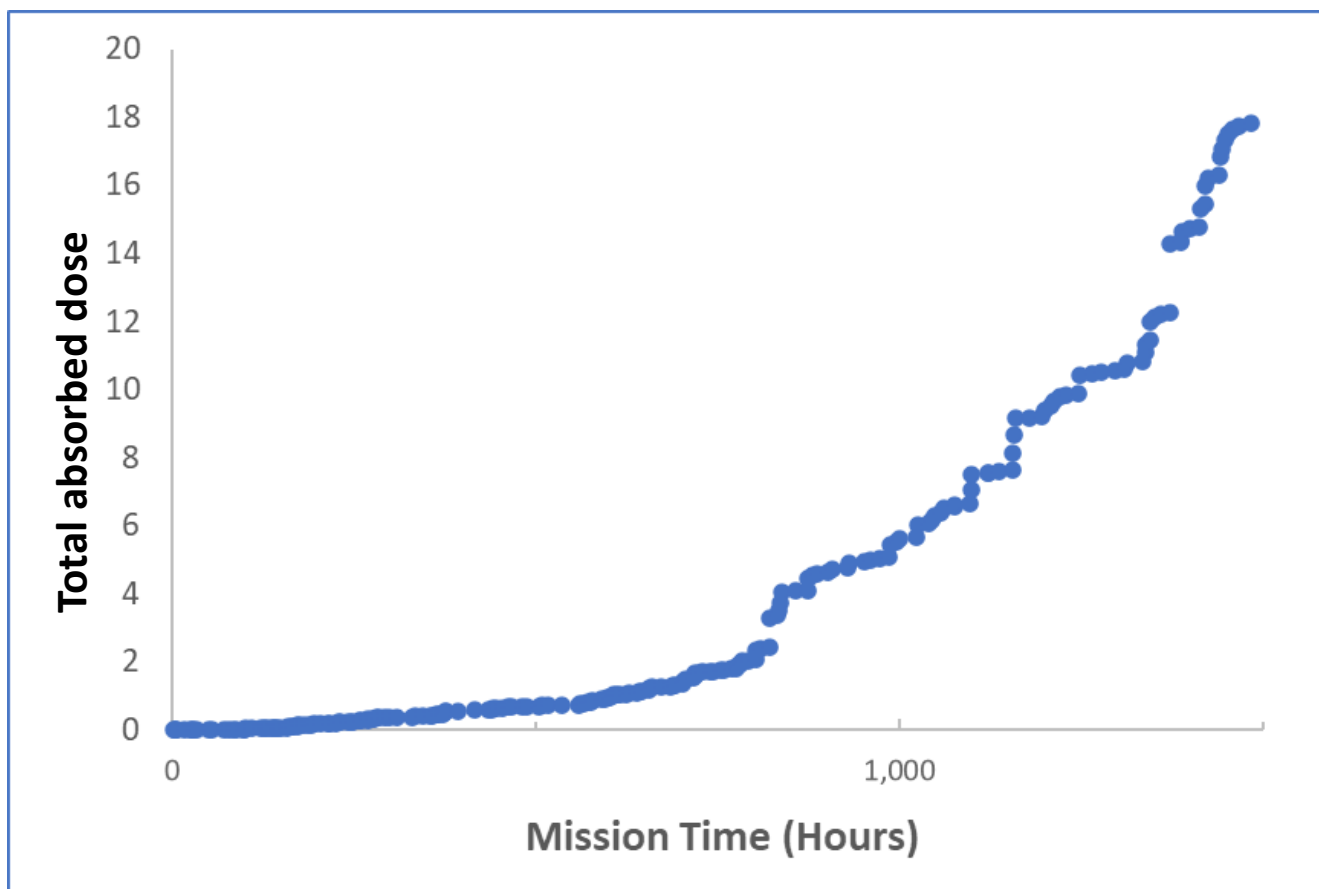
RADIAN data cube validation: NAIRAS v2 vs. CARI-7 climatology compared for Spirit Airlines commercial flight NK185 on November 30, 2021

NK185 effective dose rate starting 11/30/2021 16:14 UT





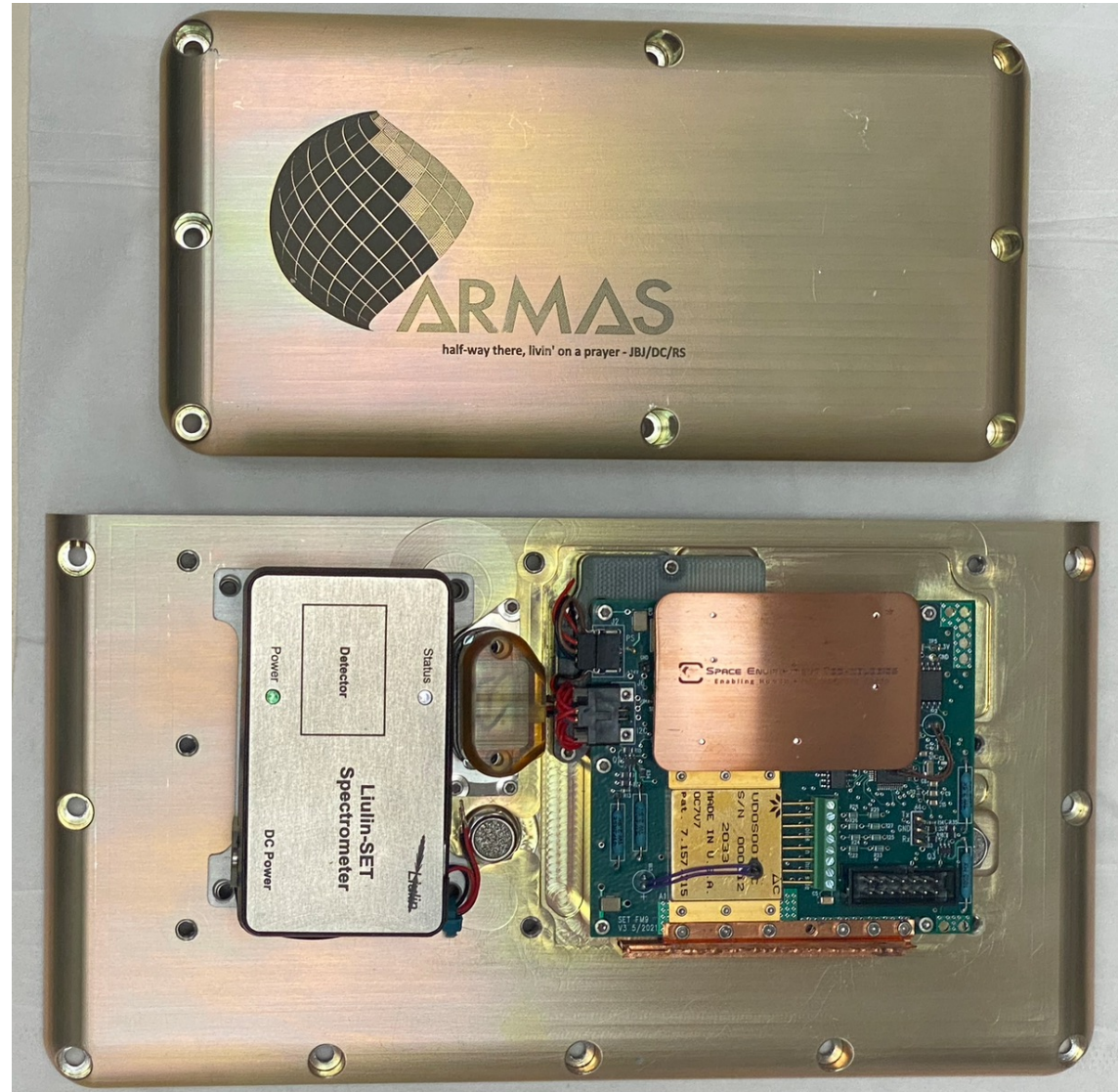
ARMAS FM8 total absorbed dose from primary particles at top of atmosphere in polar sun-synchronous orbit at 550 km July 1–September 18, 2021





Expanding radiation measurements to the top of the atmosphere: ISS

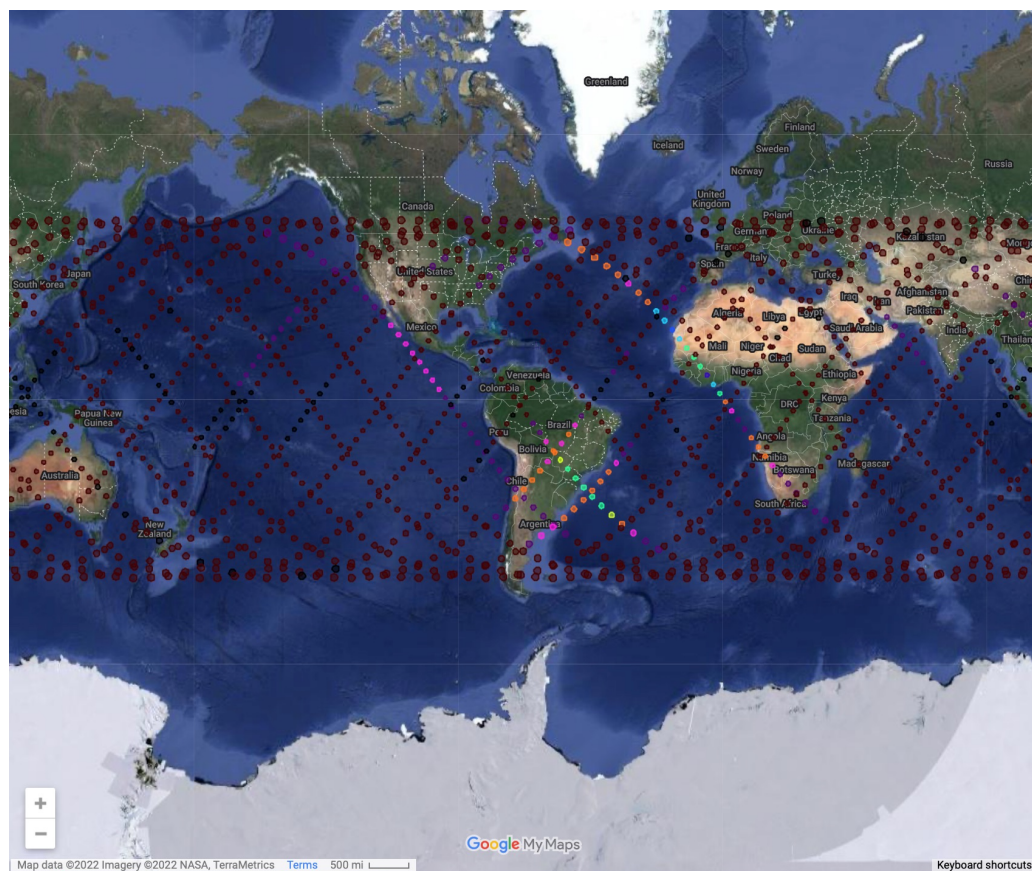
- ARMAS FM9 and Luilin-SET delivered for launch on December 10, 2021
- Measures total ionizing dose, semiconductor LET values, and energy spectrum
- ARMAS FM9 (right side) measures total ionizing dose by integrating the energy deposited in silicon across the nominal range of 100 keV to 15 MeV, including energy deposited from penetrating heavy ions, protons, and neutrons as well as from electrons, gamma-rays
- Luilin-SET (left side) measures ionizing radiation with LET between 0.1-40 keV/micron



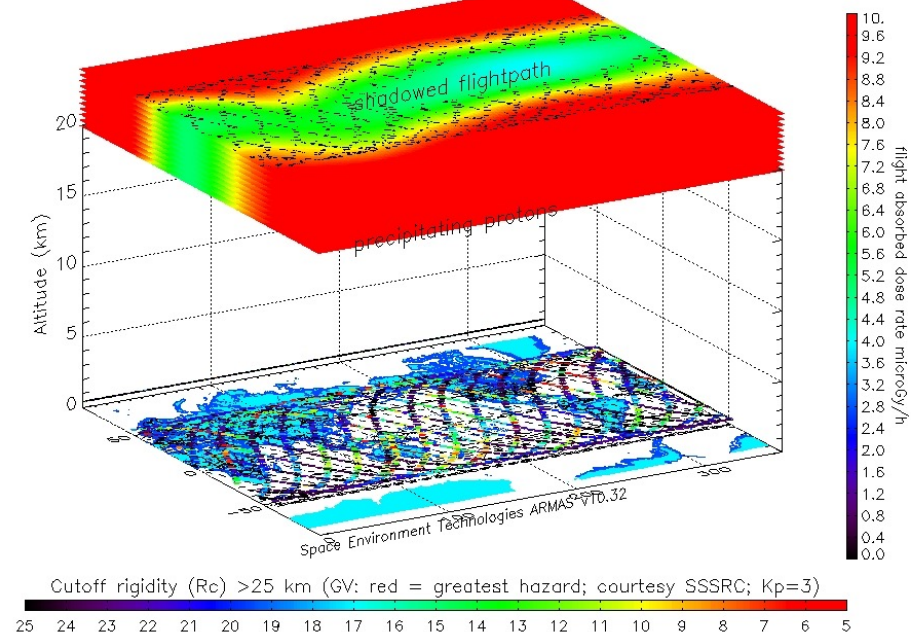
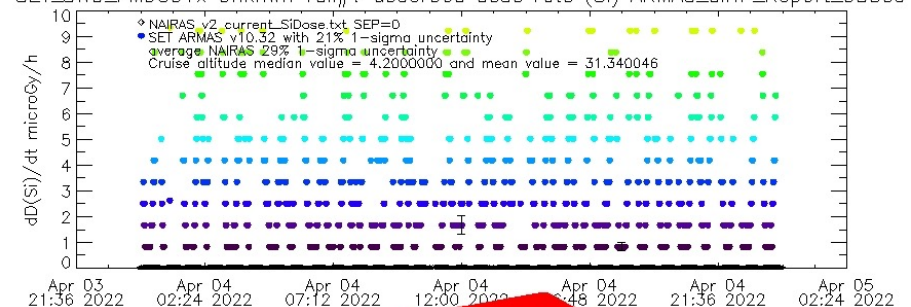
<https://spacewx.com/radiation-decision-aids/>



ARMAS FM9 dose rates in silicon from primary particles at top of atmosphere on ISS April 04, 2022



SET_SWD_FM9001x Unknwn Tail#? absorbed dose rate (Si) ARMAS_dirIP_Report_08009





Building 24/7/365 weather monitoring with ARMAS measurements on ARGOS HALE UAV

The HALE UAV Vehicle

ARGOS is a lightweight UAV designed to fly autonomously for up to a year at 20 km altitude. ARGOS will open a new market for lightweight payloads (≤ 5 kg) by dramatically reducing the cost for access to the stratosphere. The primary use is for ARMAS radiation measurements and our goal is to have a fleet operating by mid-2024.



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ARGOS v1 build in progress

