



NASA Aviation Activities and Space Weather

Upper-atmospheric Space and Earth Weather eXperiment (USEWX)

**Scott Wiley, Aerospace Meteorologist,
Jacobs Technology Inc.**

Space Weather and Robotic Mission Operations
Workshop

NASA Goddard Spaceflight Center

September 17-18, 2014





NASA AFRC Space Weather Forecasting Requirements background information



Fly at high altitude

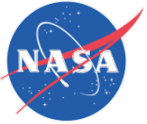
Fly at high latitude

**Pilots and Flight Crew:
human radiation dosing**

**Command & Control (C&C)
computers, Avionics,
science instruments
susceptible to SEEs**

**AFRC missions test “Space
Ready” instrumentation**

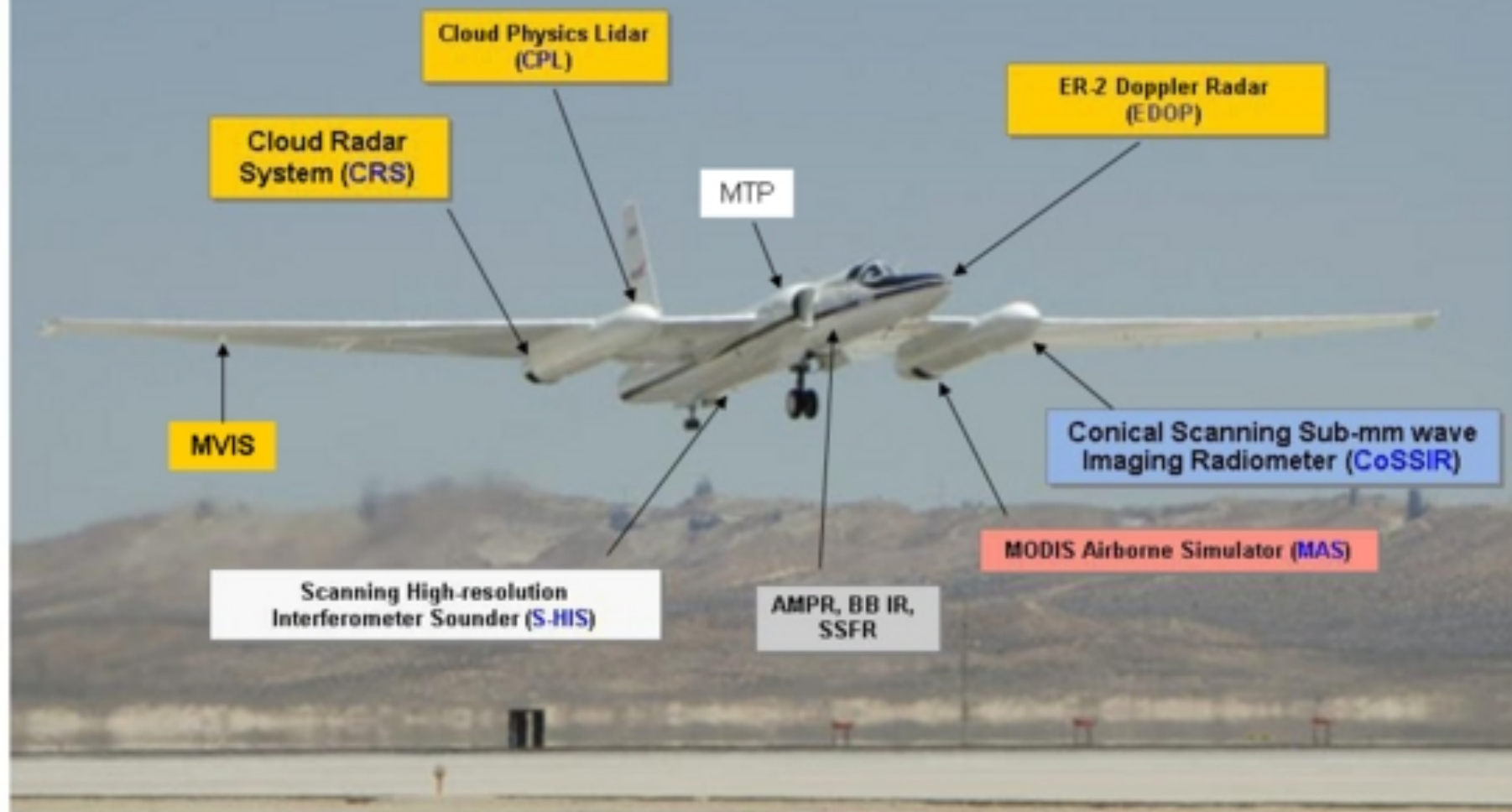
**Radio blackouts and GPS
errors affect our flights**



Space Weather Requirements at AFRC

- Identify radiation limits for go-no go flight decision making based on Human Dosing, Radio Blackouts, GPS Errors, when to Return to Base (RTB) for UAVs
- Human dosing forecasts, accuracy \pm 1 hour
- SEE and SEP forecasts, accuracy \pm 1 hour
- Flight planning forecasts, CMEs, Flares, Prominences, Geomagnetic: 1-2 days
- Forecasts for all clear time \pm 1 hour





ARMAS Lite flown on 50 flights of AFRC DC-8...more to follow



- **Arctic/Antarctic, South Atlantic Anomaly and areas of high scientific value**
- **Problem: High radiation Earth/Sun interaction**
- **Human Radiation Dosing (flight crews/PAX)**
- **Radio Blackouts**
- **GPS Navigation Errors**
- **Single Event Effects (SEEs) can damage Integrated circuits and software (bit flipping)**



22 April 2010



Support of the Evaluation of Single Event Upset (SEU) Risk in the Global Hawk UAS from
Increased Neutron Flux at High Latitudes

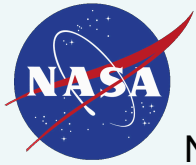
by

Dr. David Fahey (NOAA/ESRL) and Dr. Paul Newman (NASA/GSFC),
GloPac Project Scientists

Dr. Hal Maring (NASA/HQ), Radiation Sciences Program Manager

Background: In the GloPac Arctic Flight Tech Brief (20 April 2010) for the GloPac Arctic flight, additional risk was included for an SEU failure of the Global Hawk IMMC at high latitudes (up to 85°N). The analysis was based, in part, on the latitude dependence of the cosmic-ray neutron flux as analyzed by **Normand and Baker** and presented on Slide #11 of the Tech Brief (see next slide).

Objective: Evaluate the representativeness of the **Normand and Baker** results for neutron fluxes that are likely to be encountered during the Arctic flight at solar minimum conditions in April 2010 (See Appendix B).

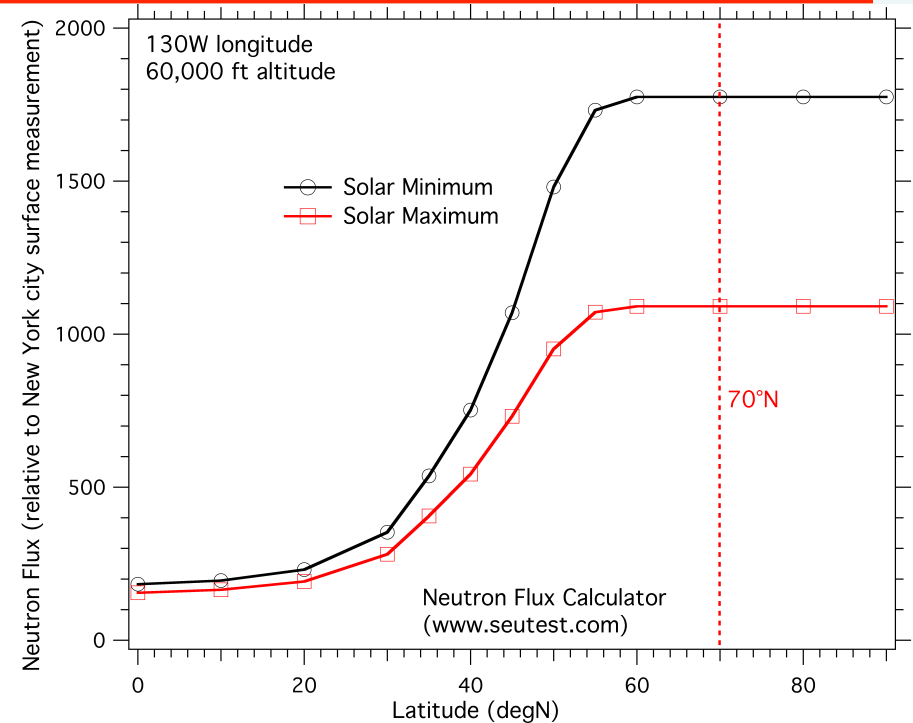
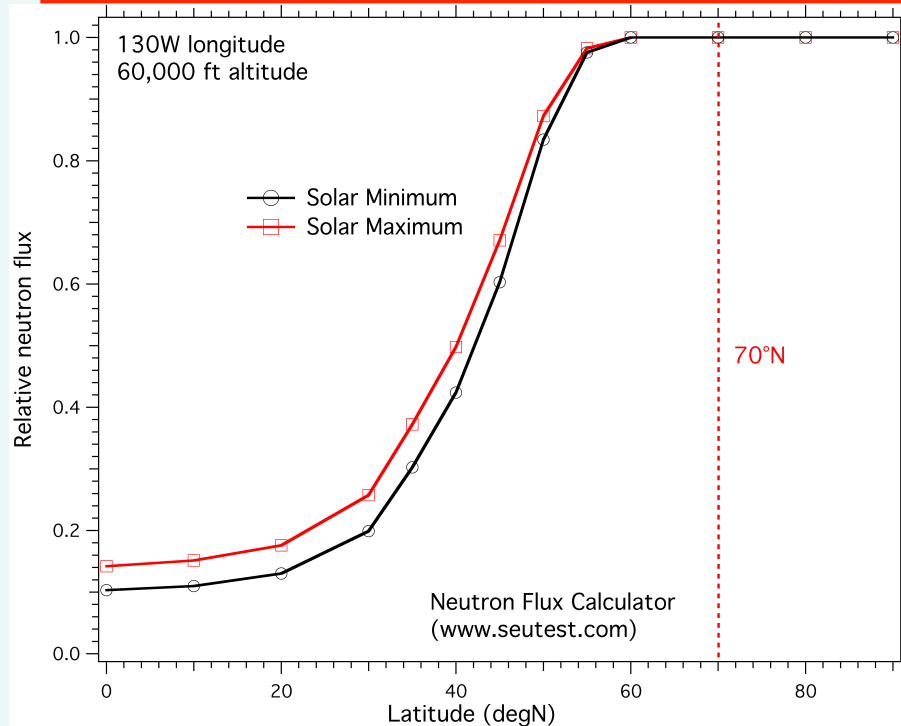


Calculations of the latitude dependence of neutron flux



Neutron flux normalized to 90°N

Neutron flux relative to NYC



- Flux values are normalized to the value at 60° latitude.
- The variation in latitude gradient is less than 10% between solar min and max.
- Normand and Baker results (Fig. 2) match the latitude dependence at solar maximum.
- No change in flux occurs above 60°N.

- Flux values are referenced to the value measured in New York City at the surface.
- The flux changes by a factor of 1.6 between solar minimum and solar maximum for latitude > 60 degrees.

(www.seutest.com calculations represent the most current scientific understanding of the dependences of neutron flux on altitude, latitude, and solar cycle.)



SOFIA missions: Long duration, High Altitude, Night Flights. Radiation Concerns?





IKHANA

Research platform



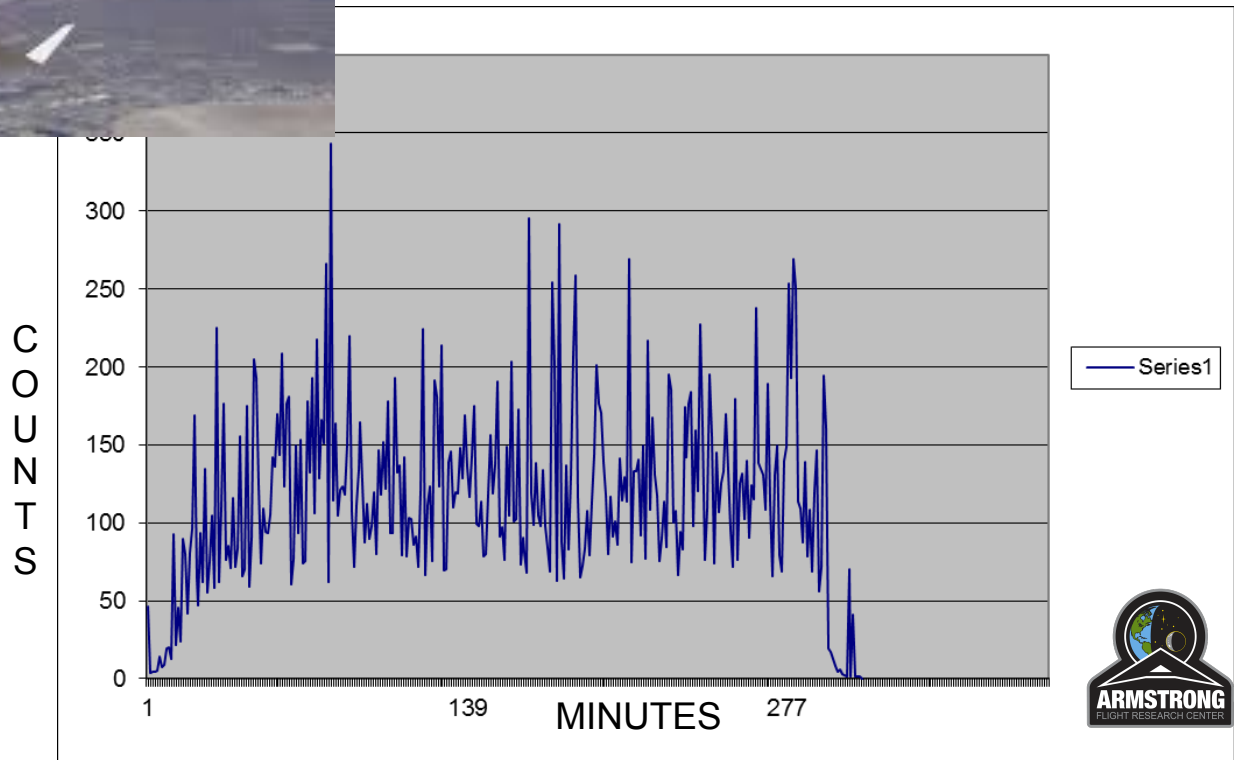
*Needed Space and Weather
data for IKHANA
Fly in the Arctic for MIZOPEX
Summer 2013 during the
Solar Maximum
Cause for concern?*



Hawk dose measurements on AFRC C-20 over Iceland



Preliminary data
needing further analysis



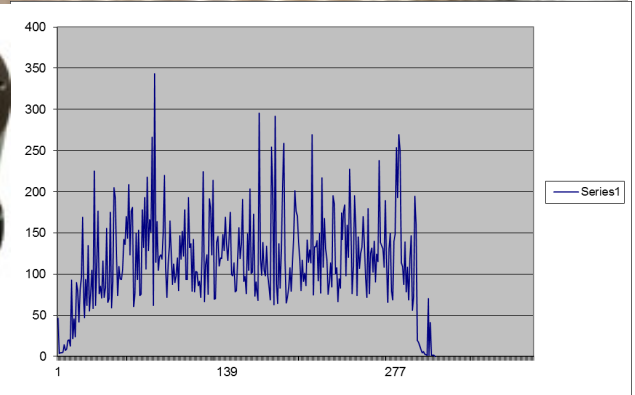
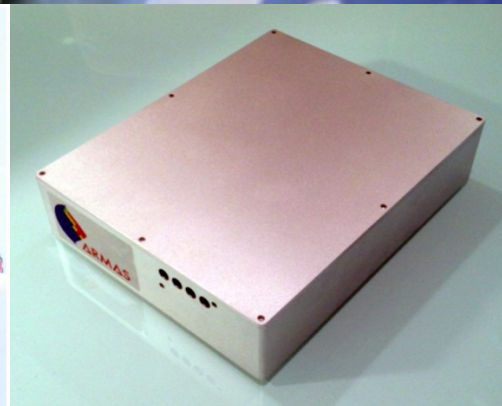
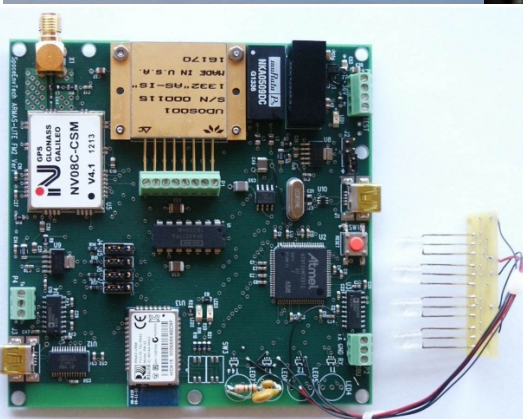
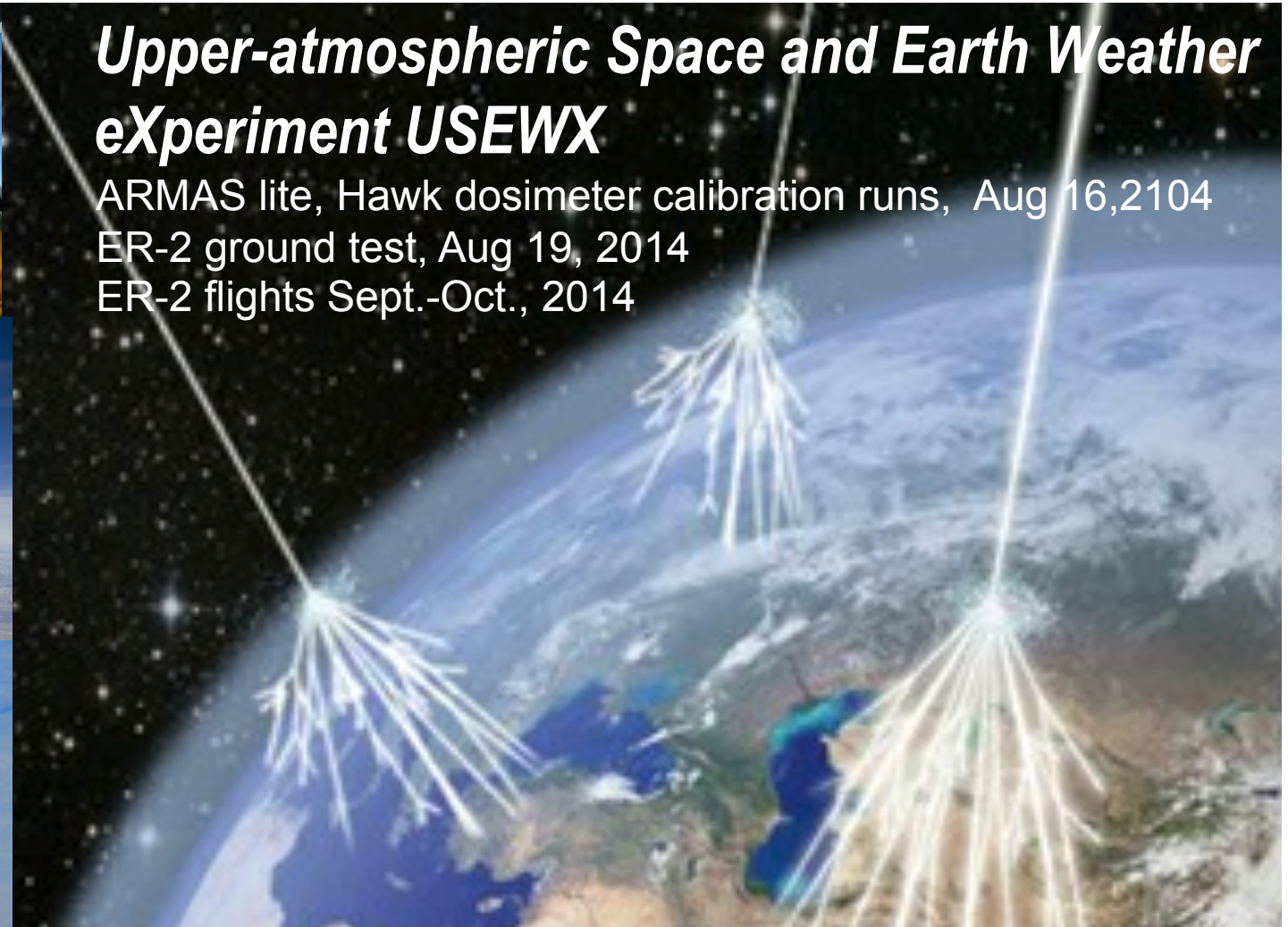


SEE related failure? Air Data Inertial Reference Unit: 122 injured, 12 serious, 39 hospitalized. A cause for concern?



Upper-atmospheric Space and Earth Weather eXperiment USEWX

ARMAS lite, Hawk dosimeter calibration runs, Aug 16, 2104
ER-2 ground test, Aug 19, 2014
ER-2 flights Sept.-Oct., 2014





USEWX instrumentation

- Far West Hawk TEPC Dosimeter(s)
 - 2 prototype Hawks from LaRC
 - 1 loaner from Prairie View A & M
 - 1 loaner from SolarMetrics
- Automated Radiation Measurement for Aviation Safety: ARMAS-Lite: silicone dosimeter purchased from Space Environment Technologies SET
- Thermalized Neutron Measurement experiment TinMan-Thermal Neutron detector provided by Honeywell



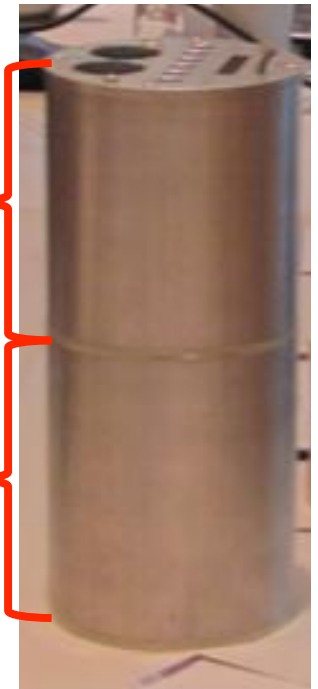
Far West Hawk TEPC Dosimeter

- **TEPC-Tissue Equivalent Proportional Counter (dose to humans) and the TEPC is a true Micro-dosimeter**
- **Gas filled active micro-dosimeter with 2 μm diameter spherical volume of human tissue equivalent plastic**
- **Measures absorbed dose (D) and dose equivalent (H) to tissue in mixed radiation fields**
- **Hawk is self contained, battery powered, passive and GPS equipped**
- **Provides a radiation quality factor (Q)**
- **Flew on AFRC/ER-2 in the 1990s**
- **Flown on United and Virgin Atlantic 747s**
- **Placed in aluminum suitcase in overhead storage**
- **Designed for aircraft**

Hawk TEPC

Spectrometer,
includes power
and data storage

Active volume





PRAIRIE VIEW A&M UNIVERSITY

CRESSE

Center for Radiation Engineering
and Science for Space Exploration



Far West Hawk TEPC Dosimeter

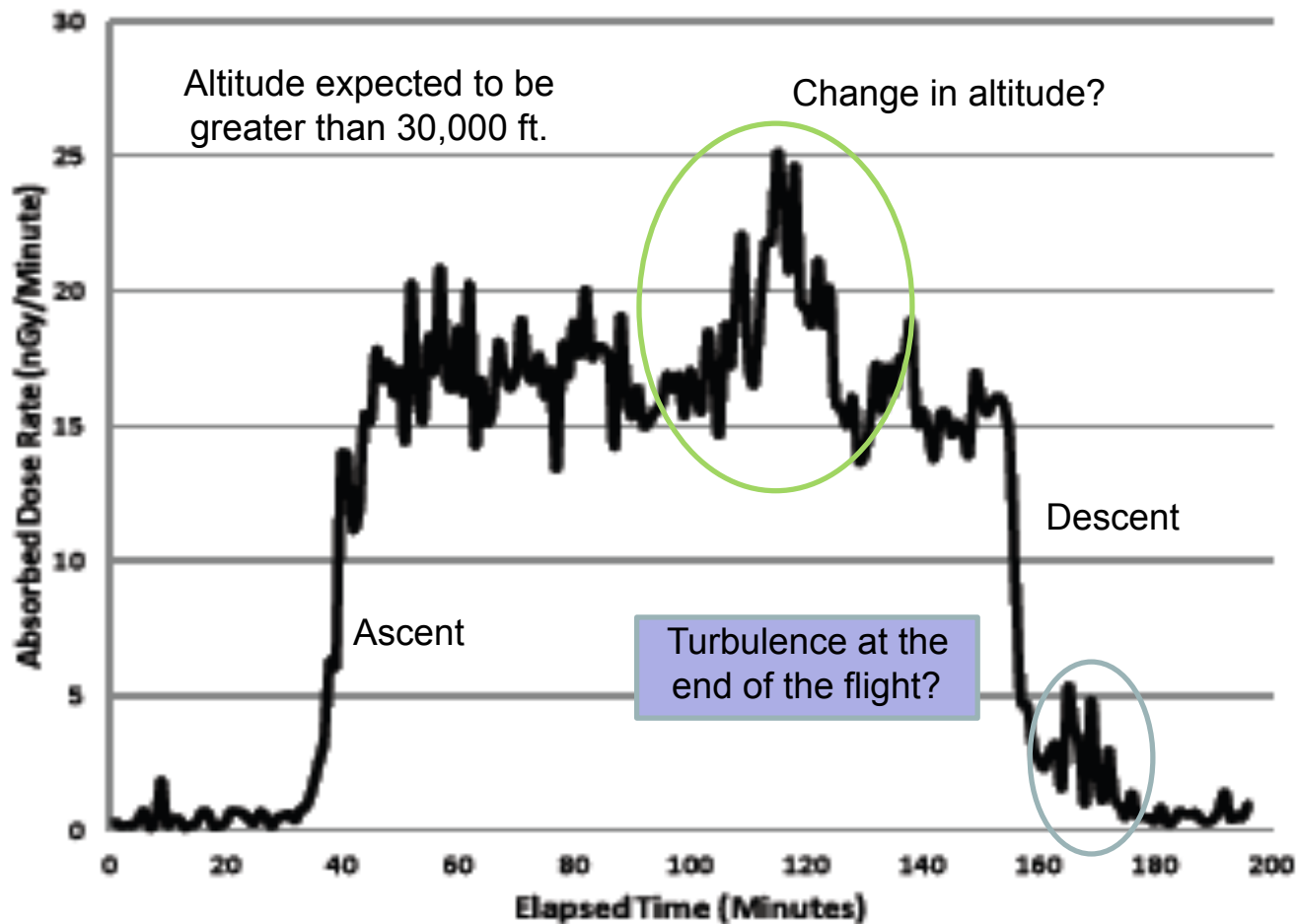
- **TEPC considered the “Gold Standard” for measuring mixed and variable radiation fields**
- **Measurements require extensive data analysis**
- **Old technology, too large, bulky, expensive for flight use**
- **Currently analyzing ground based experimental results for detailed cross-calibrations with smaller, simpler, less expensive silicon based dosimeters**
- **In flight measurements with several dosimeters needed for mixed field cross-calibrations**

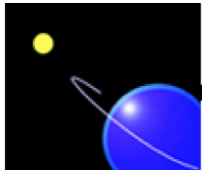




Hawk TEPC data: Feb

- Example: Houston to Los Angeles, 8/25/11, 12 am – 3am.
- Dose equivalent rate: about $1.8 \mu\text{ Sv/hr}$, total dose equivalent : about $4 \mu\text{ Sv}$





SPACE ENVIRONMENT TECHNOLOGIES

Space Research

Space Operations

Space Standards

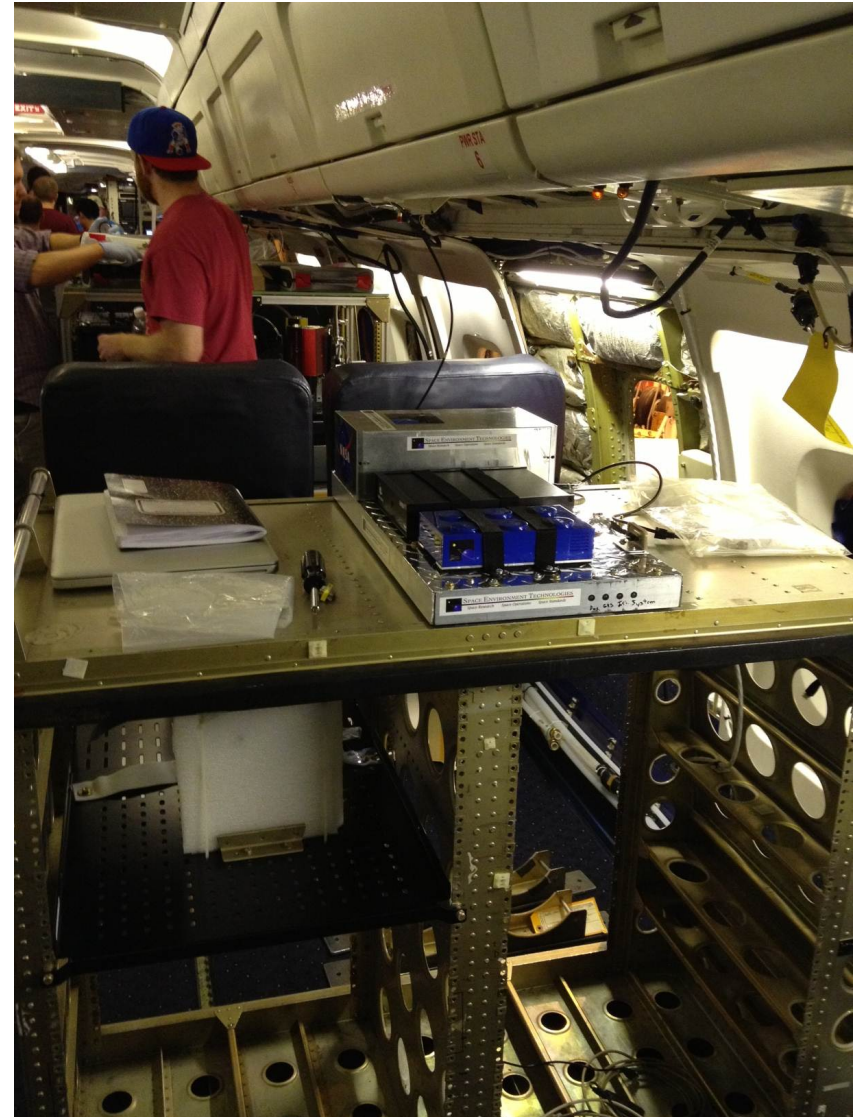
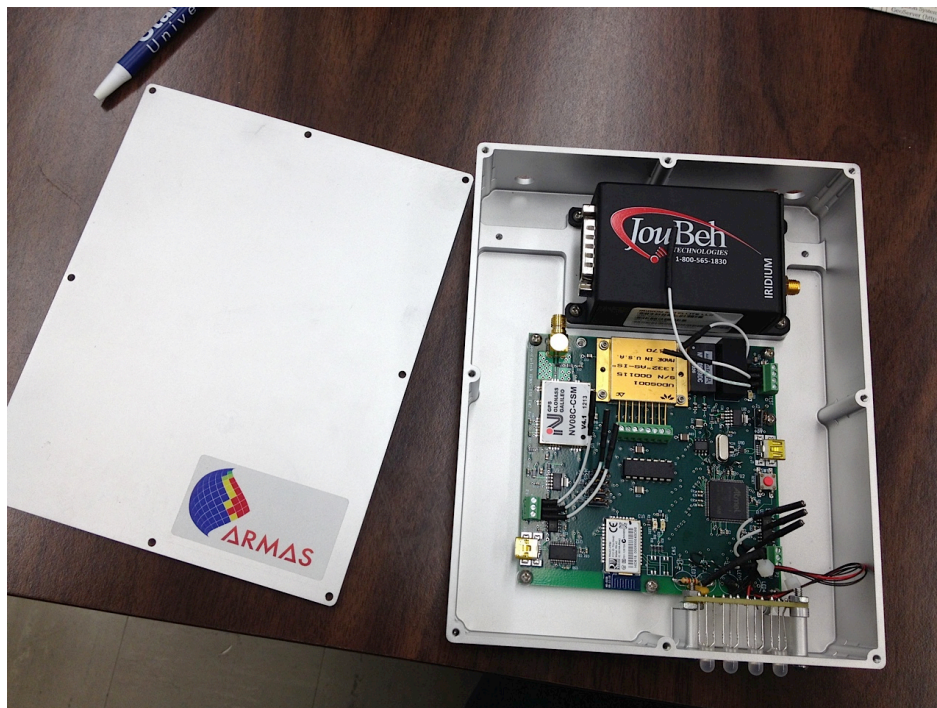
ARMAS-Lite on Rack in DC-8

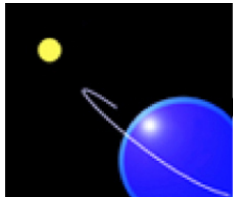
Silicone based dosimeter

Data telemetered via Iridium to LaRC/SET

LaRC uses data to verify NAIRAS model

15 min data latency to smartphone app





SPACE ENVIRONMENT TECHNOLOGIES

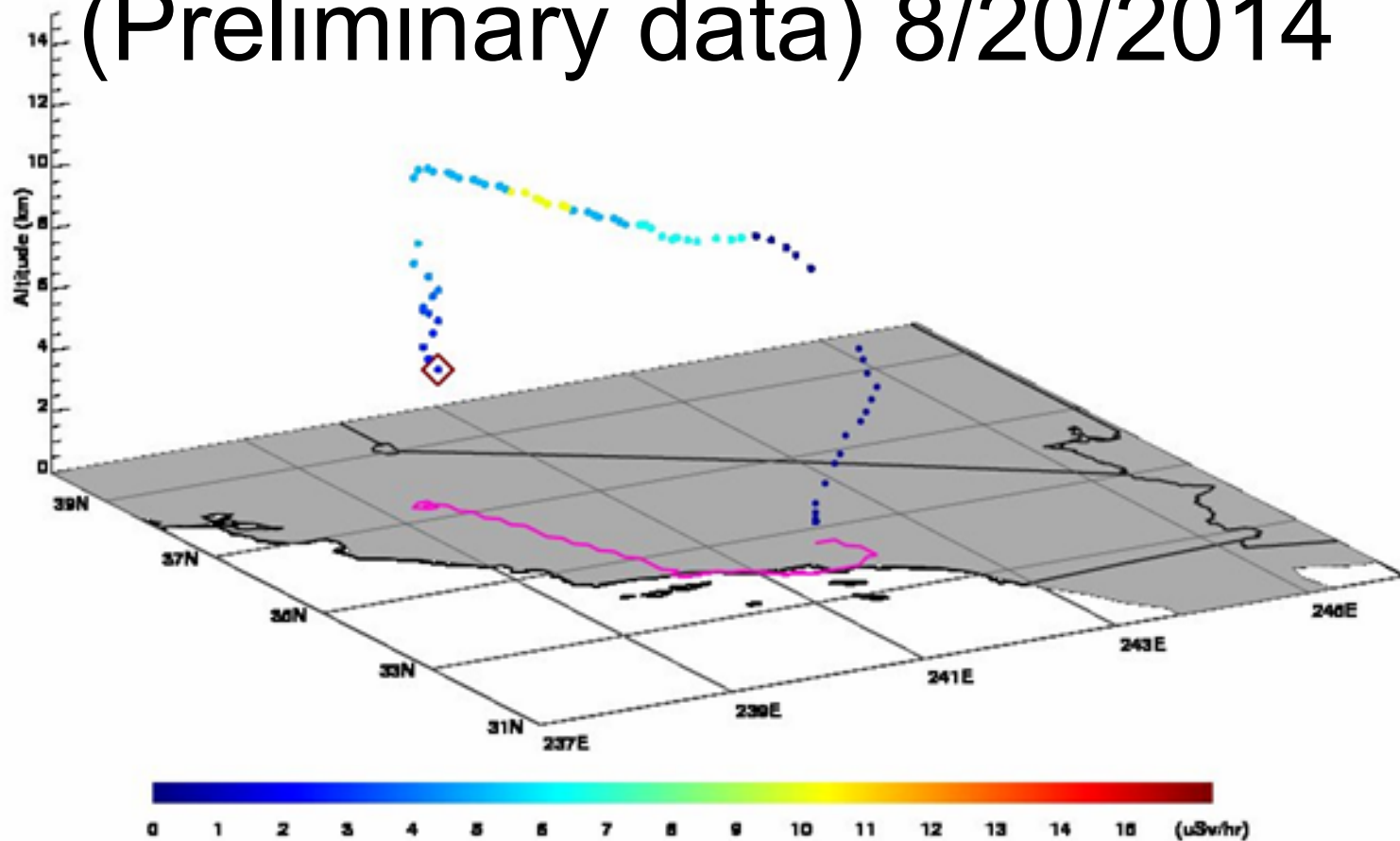
Space Research

Space Operations

Space Standards

ARMAS LITE Dose rate on DC-8 (Preliminary data) 8/20/2014

Effective dose rate: last updated at 2014-08-27 21:31:30 GMT



7/2/2009



Guess who was on
DC-8 on 8/20/2014?



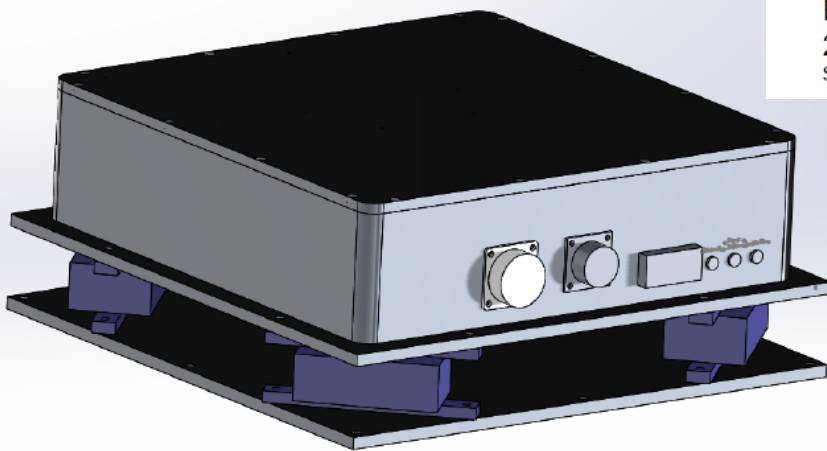
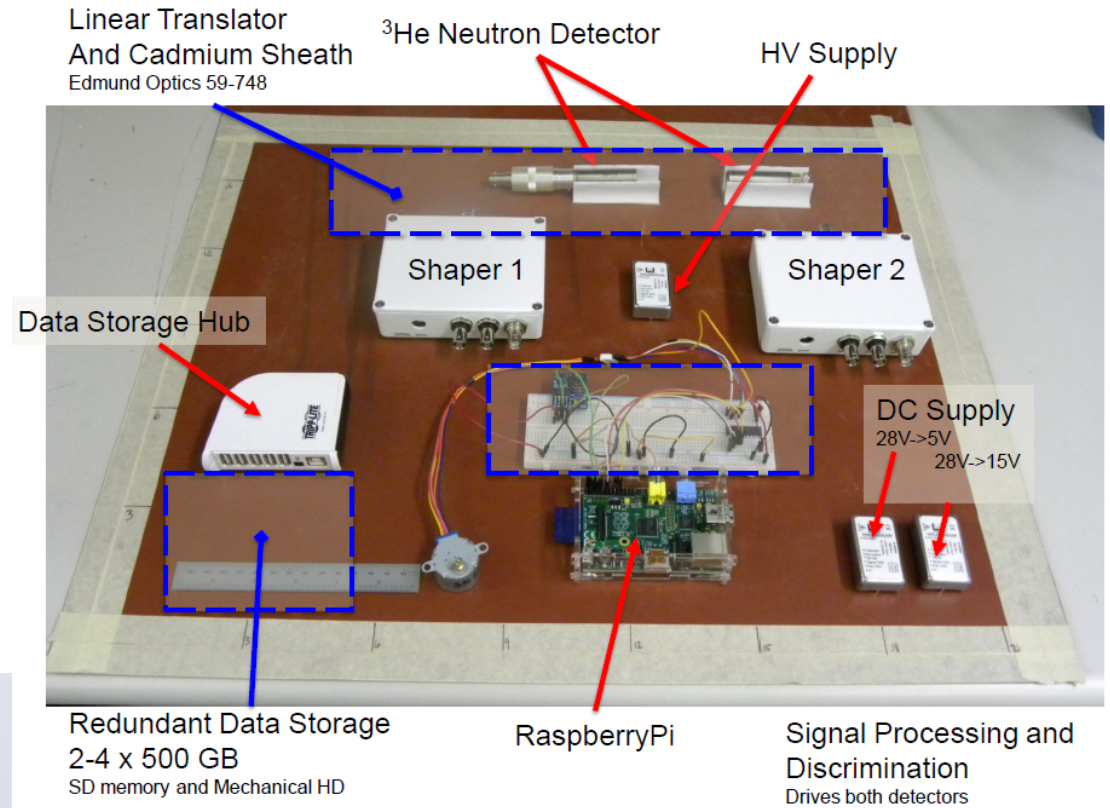
Thermalized Neutron Measurement Experiment (TINMAN)

Honeywell

- **Purpose**
 - Monitor and record the thermal energy neutron environment within various aircraft types and locations.
 - ◆ FL400 is 300X > neutron flux @ sea level
- **Reason**
 - IC manufacturers using Boron10, ICs more susceptible to thermal energy neutron Single Event Effects (SEEs)-CPU halts/interrupts, corrupted data, other unknown problems
 - While the high energy neutron environment is well defined, there is inadequate information on the thermal energy neutron environment within the various aircraft types
- **Results**
 - Data from the proposed set of experiments would define the thermal energy neutron environment
 - ◆ Better information to address regulatory requirements and customer needs
 - Enable the aerospace industry to quantify the susceptibility of semiconductor devices to thermal energy neutrons
- **Aviation trending toward:**
 - Flights at higher altitudes, over polar routes
 - ◆ This is a worse SEE and radiation environment
 - Avionics/sensors/technologies becoming smaller, lower voltage
 - ◆ This leads to greater susceptibility to SEEs

Thermalized Neutron Measurement Experiment (TinMan)

Honeywell





USEWX Phase I 2014

- Cross calibrate Hawk with ARMAS-Lite: done in proton beam at Loma Linda MC August 2014
- **Airborne Radiation Measurements for Aviation Safety** ARMAS-Lite currently on AFRC DC-8 as a piggyback with ~50 flights.
- USEWX utilizing SET ARMAS Lite Development
- ARMAS Lite data transmits via Iridium to LaRC for validation of Nowcast of Atmospheric Ionizing Radiation System (NAIRAS LaRC) model
- Radiation data available via smartphone App
 - 15 min latency very near real time
- <http://sol.spacenvironment.net/~nairas/>





USEWX Phase I 2014 (cont.)

- Integrate Hawk dosimeter(s)/thermal neutron detector (TinMan) and ARMAS-Lite into ER-2 as a piggyback payload
- Share data with iSWA (GSFC) and SPACE (UCLA) databases
- Seek funding for more instruments/projects
- Analyze the data, make improvements ex. Place accelerometer on HAWK
- Move instruments around on AFRC flight assets ex. F-18, F-15, G-III, DC-8
- Prioritize by assets by mission location





USEWX Phase II 2015

- Dosimeters on AFRC flight assets, priority Global Hawk, GIII, F-18, F-15,
- Develop inexpensive dosimeters, cross calibrate with Hawk, ARMAS Lite, TinMan
- Integrate inexpensive dosimeters into Radiosondes (AFRC), Rocketsondes
- Compare Model space weather forecasts pre-flight along a route and post flight radiation data. Looking to refine and improve the model(s).





USEWX Phase II 2015 (cont.)

- Medipix radiation sensor or inexpensive dosimeter and integrate them into radiosondes and test fly them (AFRC)
- Distribute dosimeters/interface to partners
- SWPC/GSFC forecast Space Weather Day of interest for coordinated balloon launches
- Worldwide coordinated effort-SWPC , TIS, CERN, NWS, AFRC, DLR, TIS, CERN, ISS, Satellite data, STEREO, SOHO, etc.

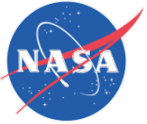




Weather Balloon Launch in support of flight testing

- AFRC Radiosonde equipment
- AFRC Research Instrumentation
- Select and build inexpensive medipix like radiation sensor
- Flight test dosimeter package with Vaisala Radiosonde interface





AFRC Radiosondes



- AFRC has radiosonde experience
- Interface already developed from both radiosonde manufacturers
- Integrate data into weather data stream
- Coordinate with TIS/STEM to bring dosimeters to NWS offices for a coordinated flight on space weather day of interest
- Need GSFC to assist with forecasting SWPC/GSFC

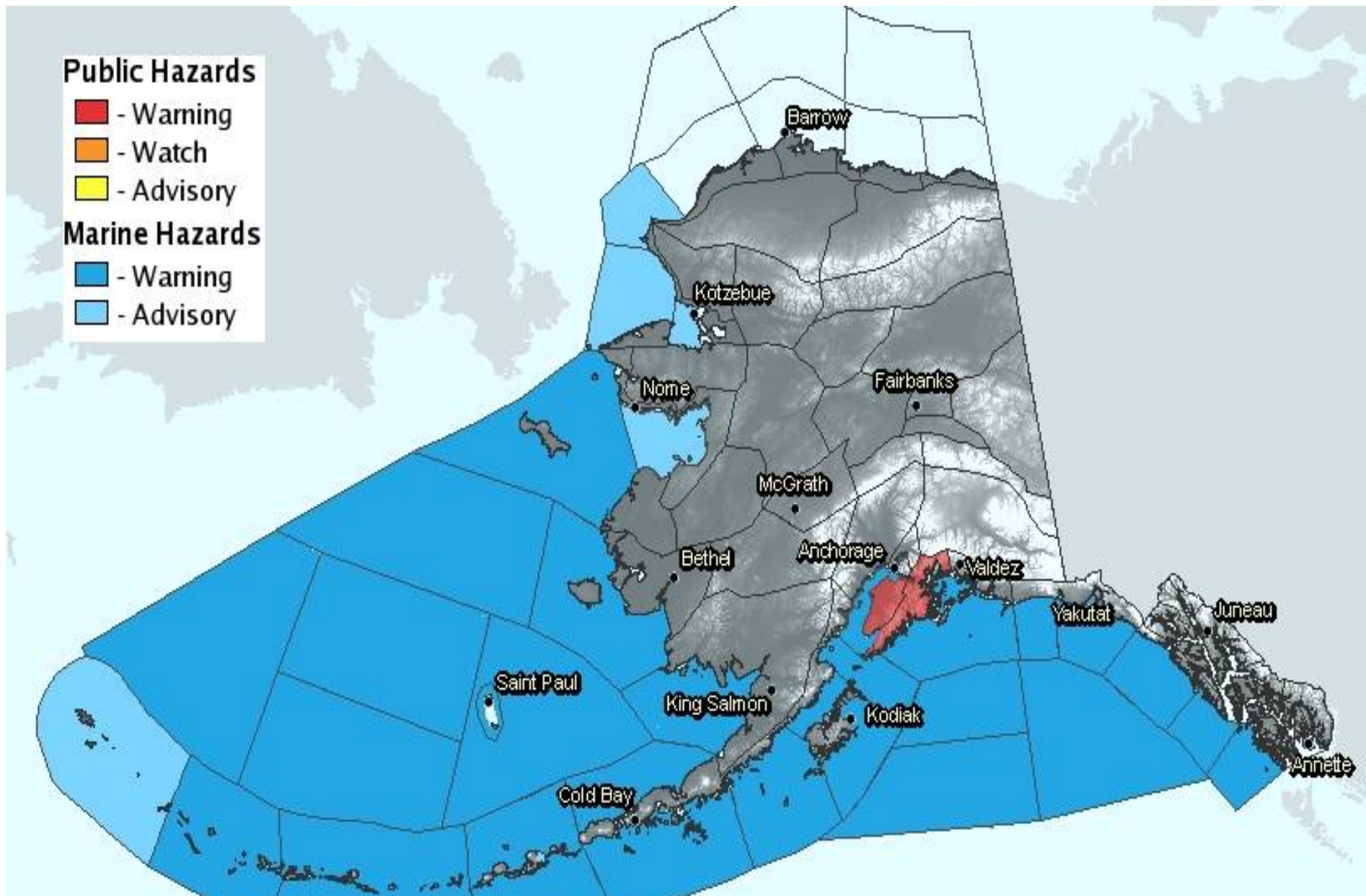




Medipix sensor with USB port

- Inexpensive
- New Technology
- Small, Portable
- Easy Interface
- Integrate with weather balloon instrumentation
- Provide radiation data to the pilot, teachers, students, partners





Alaska Region Upper Air Program is comprised of 13 stations: Anchorage, Annette, Barrow, Bethel, Cold Bay, Fairbanks, King Salmon, Kodiak, Kotzebue, McGrath, Nome, Saint Paul Island, and Yakutat.



Partners/Potential Partners

- Current Partners: Space Environment Technology (SET), Honeywell, Prairie View A & M, Other NASA Centers, Teachers in Space (TIS), STEM
- NOAA: Space Weather Prediction Center (SWPC), National Weather Service (NWS)
- International: DLR, CERN
- FAA, Boeing, Northrop Grumman, General Atomics, other UAV platforms



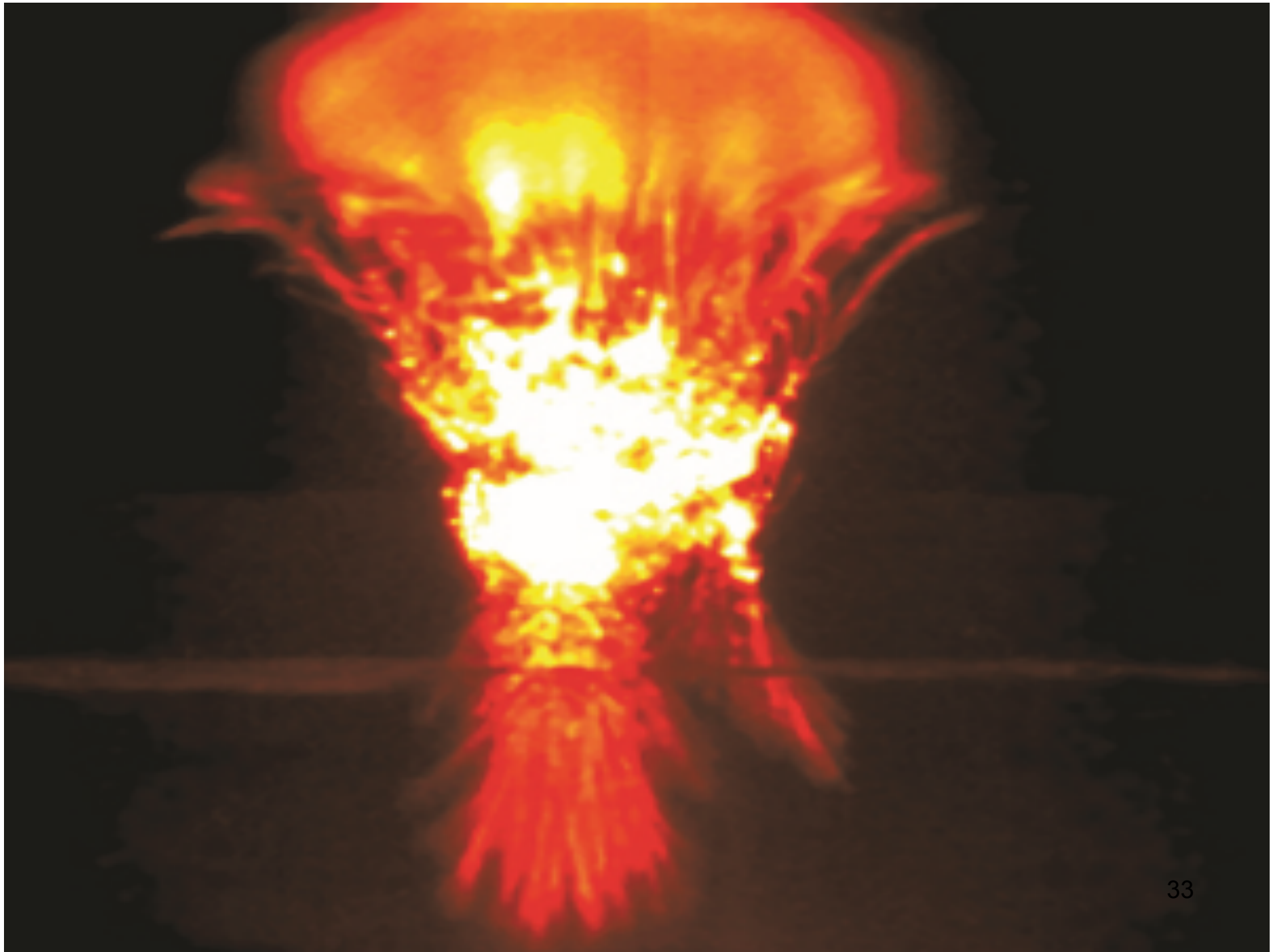


LiveScience via Fox News

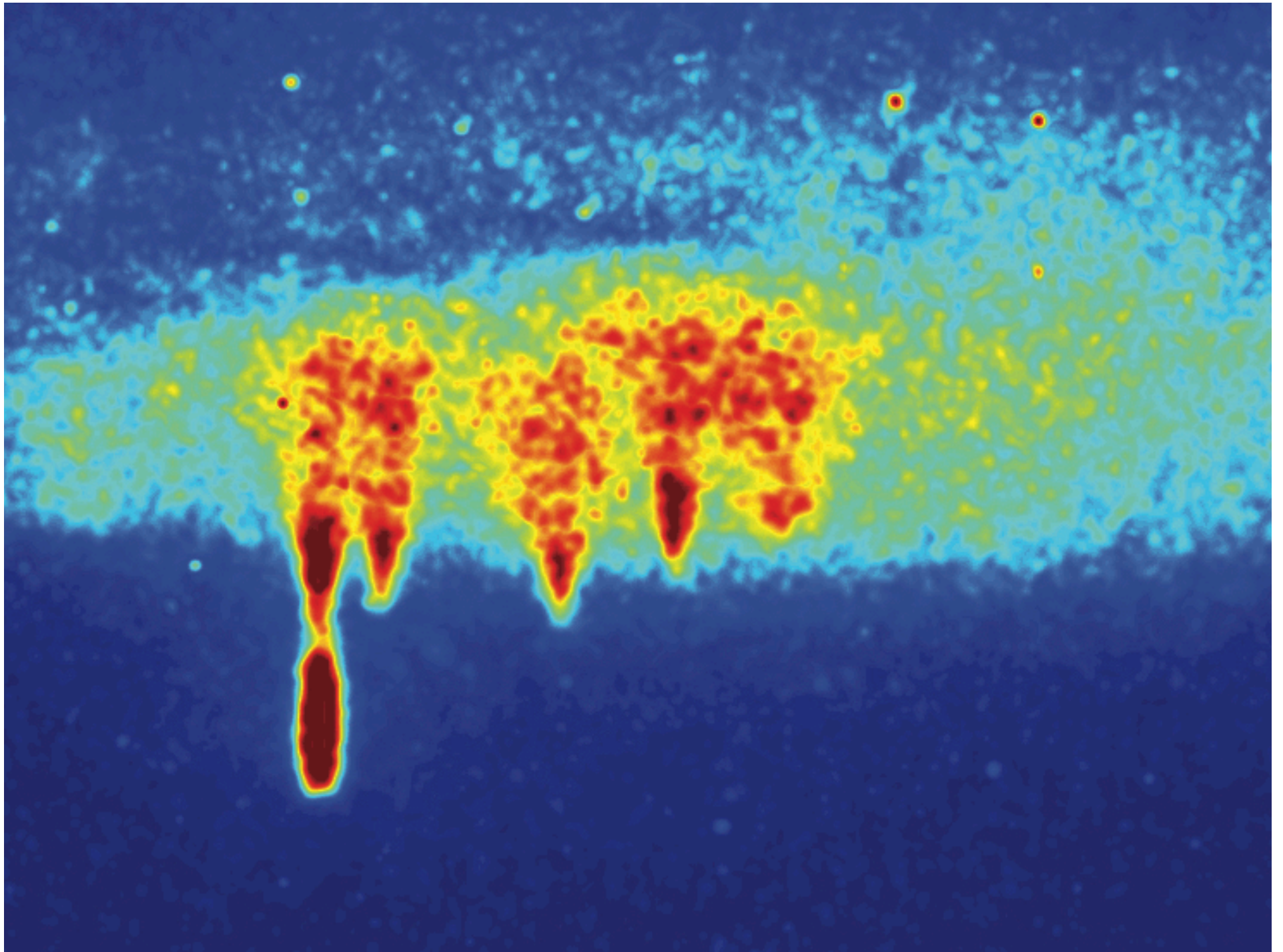


<http://www.foxnews.com/science/2014/05/12/origin-mysterious-jellyfish-lightning-sprites-revealed/>











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Questions?



NASA Dryden Flight Research Center Photo Collection
<http://www.dfrc.nasa.gov/Gallery/Photo/index.html>