NASA Armstrong Flight Research Center AVIATION ACTIVITIES in Space Weather Upper-atmospheric Space and Earth Weather eXperiment (USEWX)

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Space Weather and Robotic Mission Operations Workshop

NASA Goddard Spaceflight Center

September 29-30, 2014

Why is NASA AFRC concerned about Space Weather?

- 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

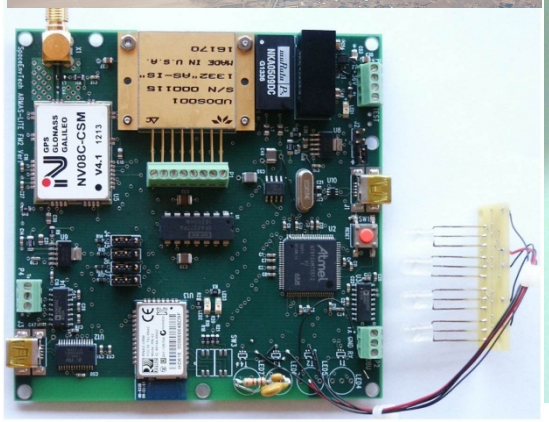
SEE related failure? Air Data Inertial Reference Unit: 122 injured, 12 serious, 39 hospitalized. A cause for concern?

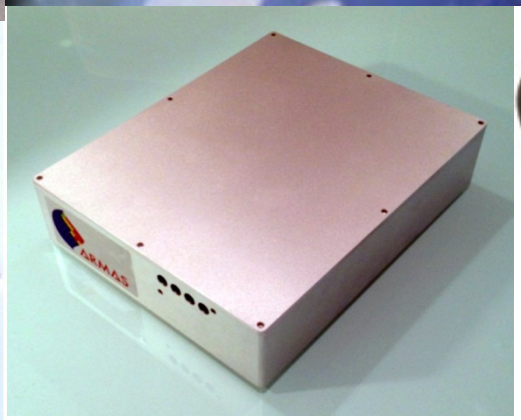
Space Weather Needs at AFRC

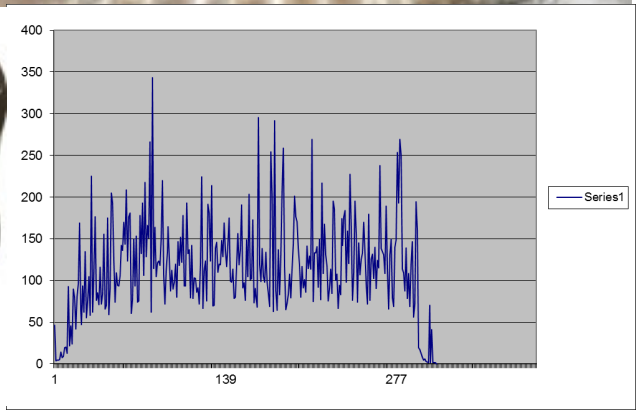
- Identify radiation limits for go-no go flight decision making based on Human Dosing, Radio Blackouts, GPS Errors, when to Return to Base (RTB) for UAVs
- Human dosing forecasts, accuracy ± 1 hour
- SEE and SEP forecasts, accuracy ± 1 hour
- Flight planning forecasts, CMEs, Flares, Prominences, Geomagnetic: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

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 flight Sept. 9th, 2015





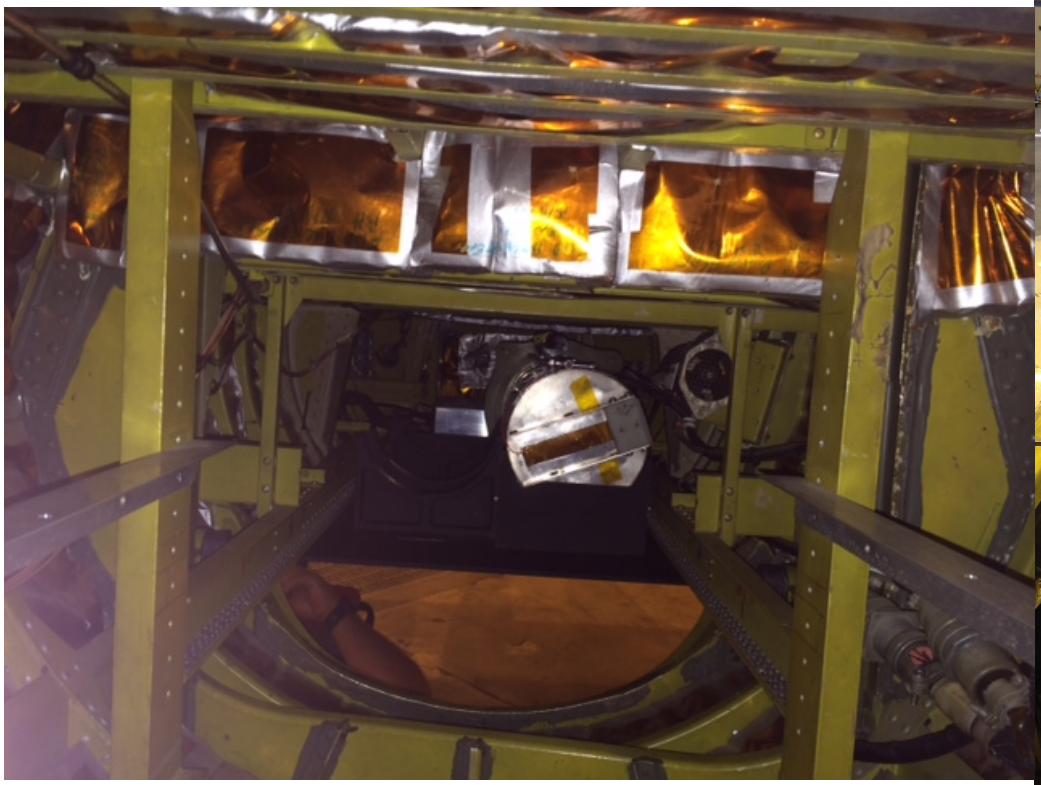


Radiation and Dosimetry eXperiment RaD-X LaRC

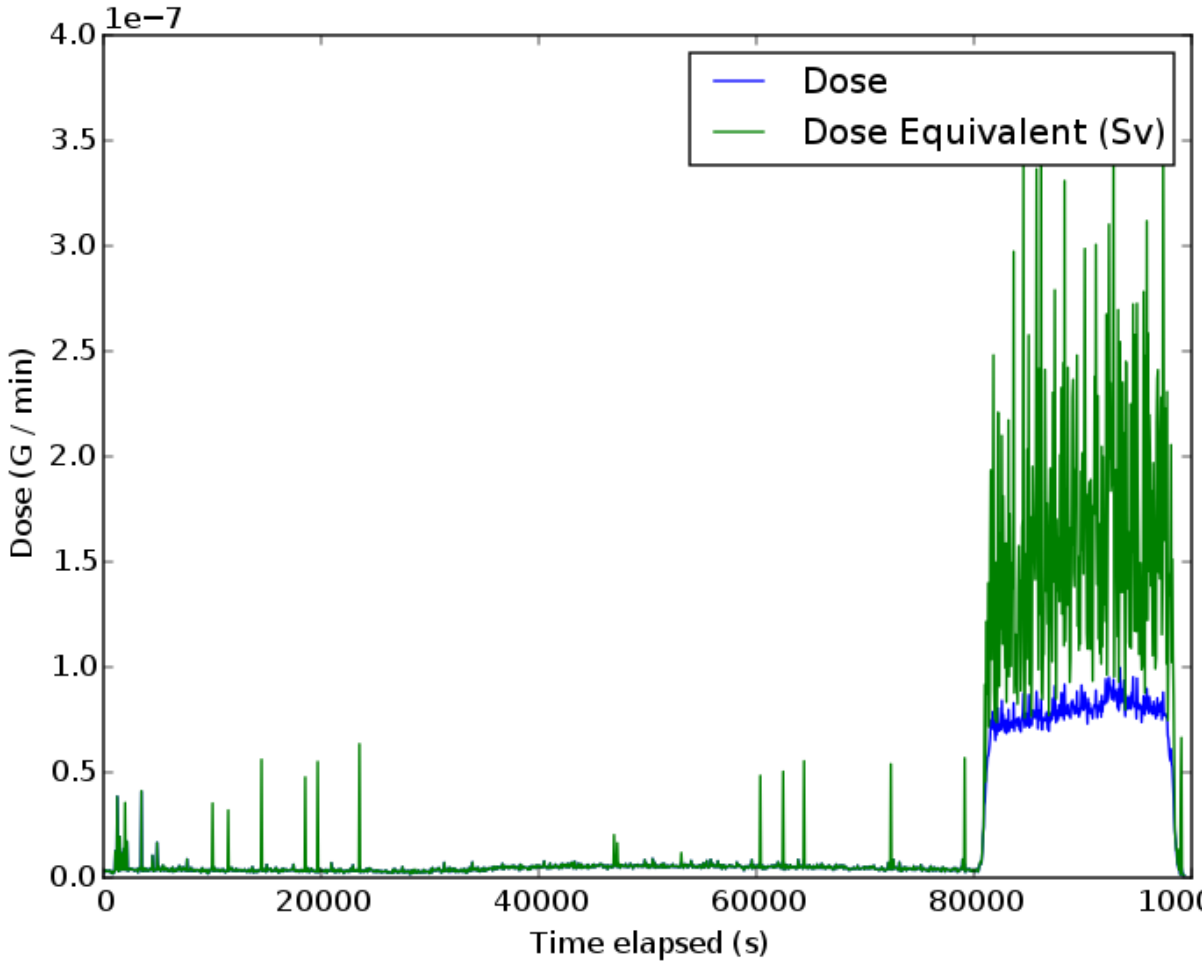
- **http://science.larc.nasa.gov/radx/**
- **http://rad-x.larc.nasa.gov**


ER-2 superpod
lightning-gamma radiation flashes?

Hawk, TinMan in ER-2 Superpod and ARMAS FM-3 in ER-2 Q-bay



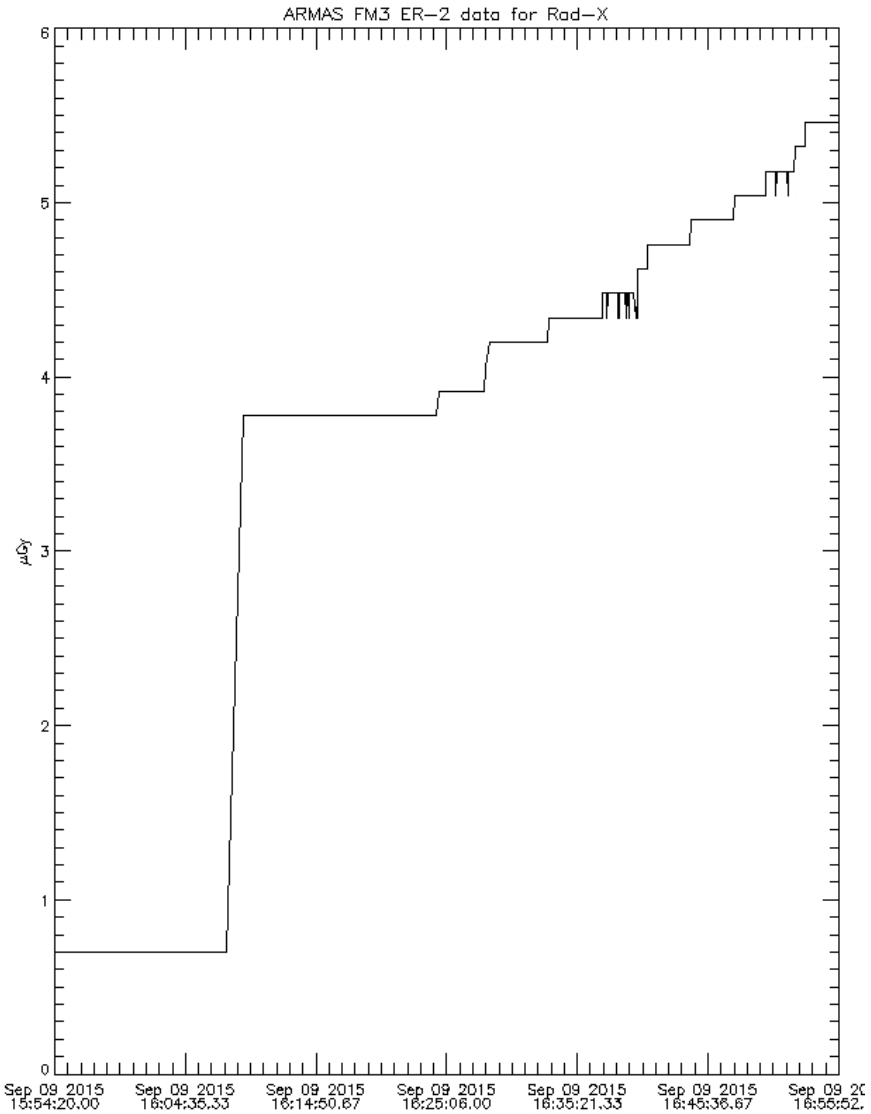
Hawk Dosimeter Data
ER-2 on 9-9-2015 for RaD-X



Preliminary data, Ongoing analysis

Credit: Jones SolarMetrics, Mertens, LaRC

ARMAS-Lite Flight Module 3Data ER-2 on 9-9-2015 for RaD-X



Preliminary data,
Ongoing analysis

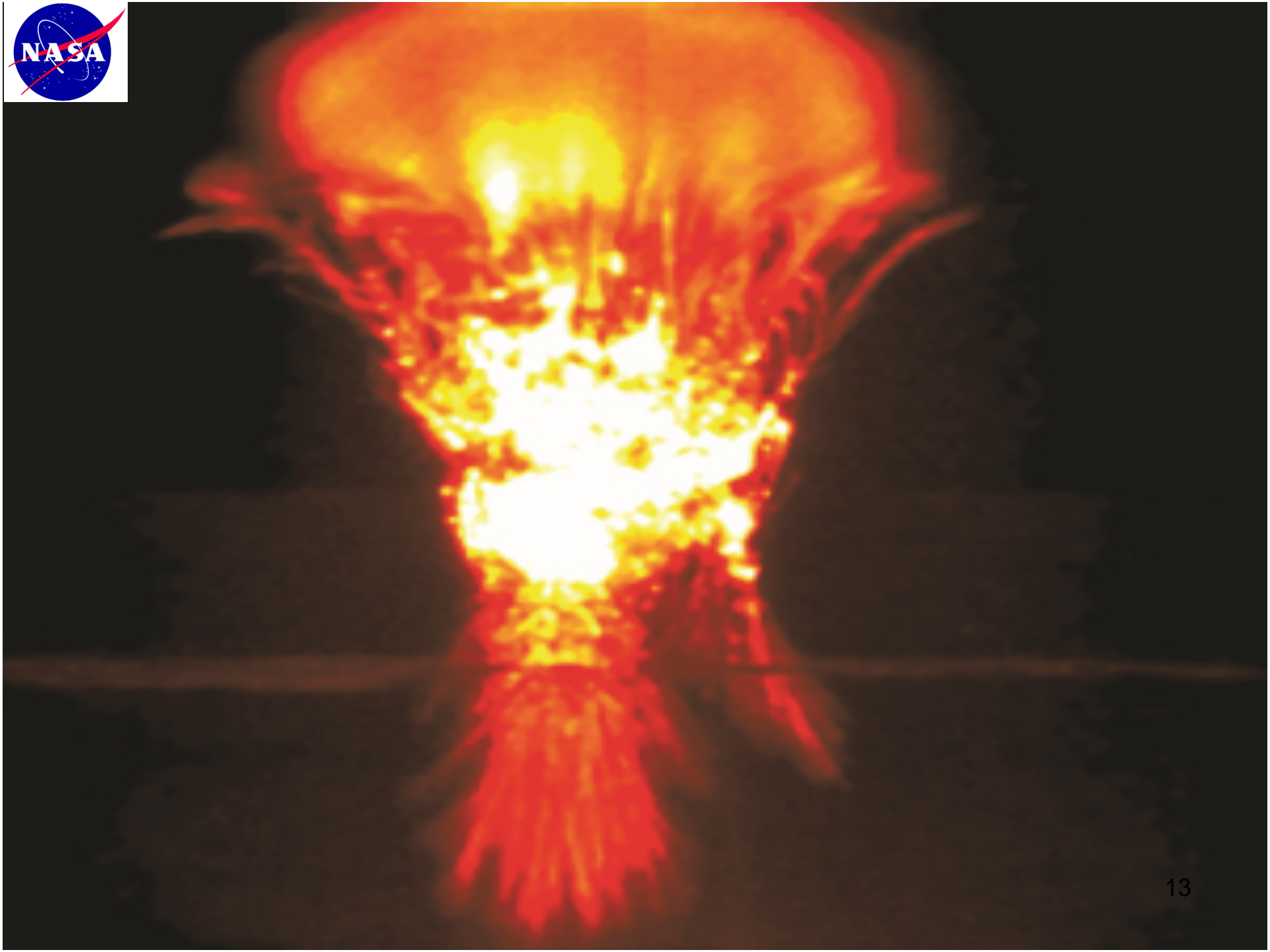
Credit: Tobiska, SET

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)**

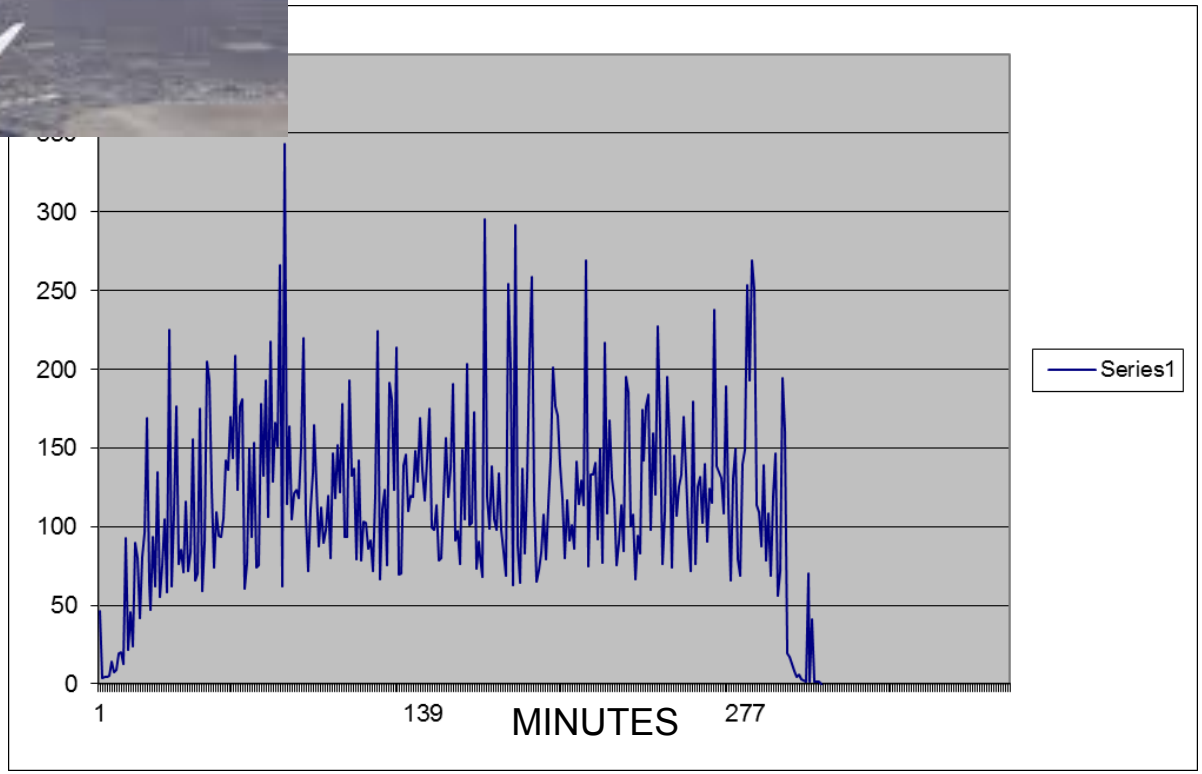
LiveScience via Fox News

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



Hawk dose measurements on AFRC C-20 over Iceland

Preliminary data needing further analysis

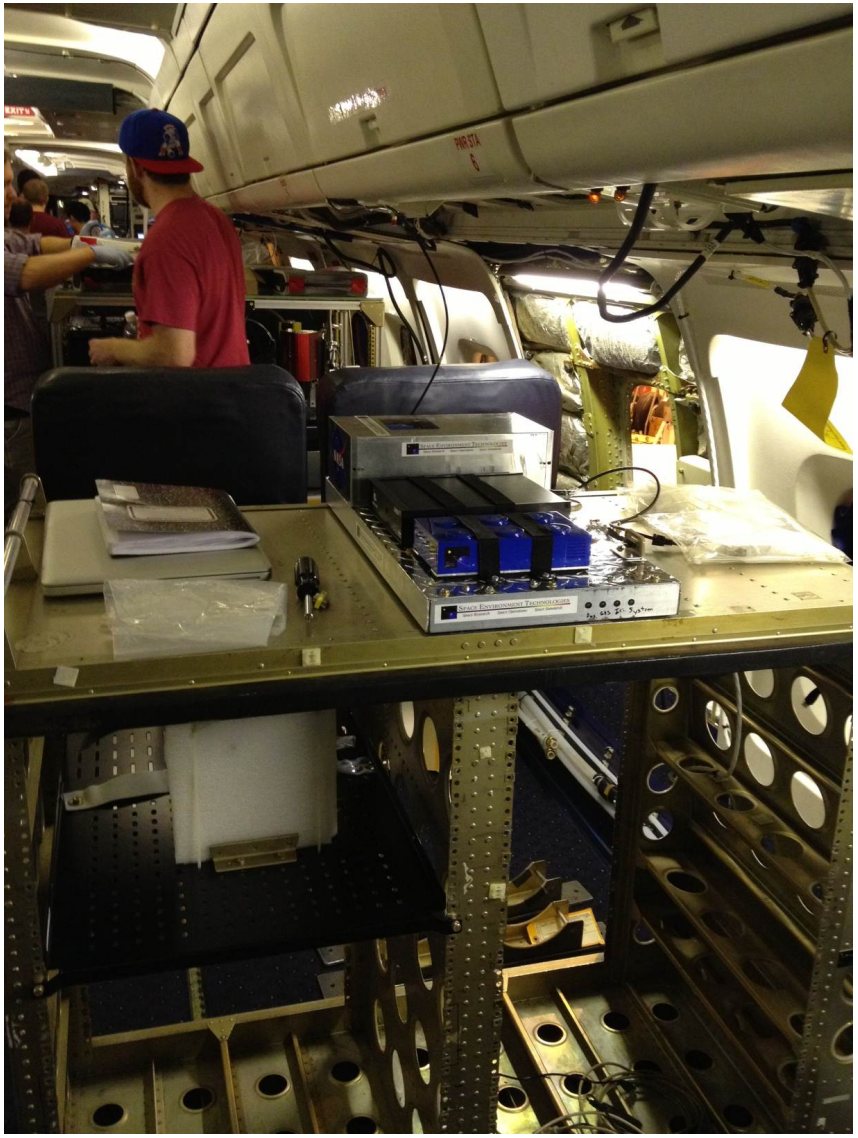


SPACE ENVIRONMENT TECHNOLOGIES

Space Research *Space Operations* *Space Standards*

ARMAS-Lite on Rack in DC-8

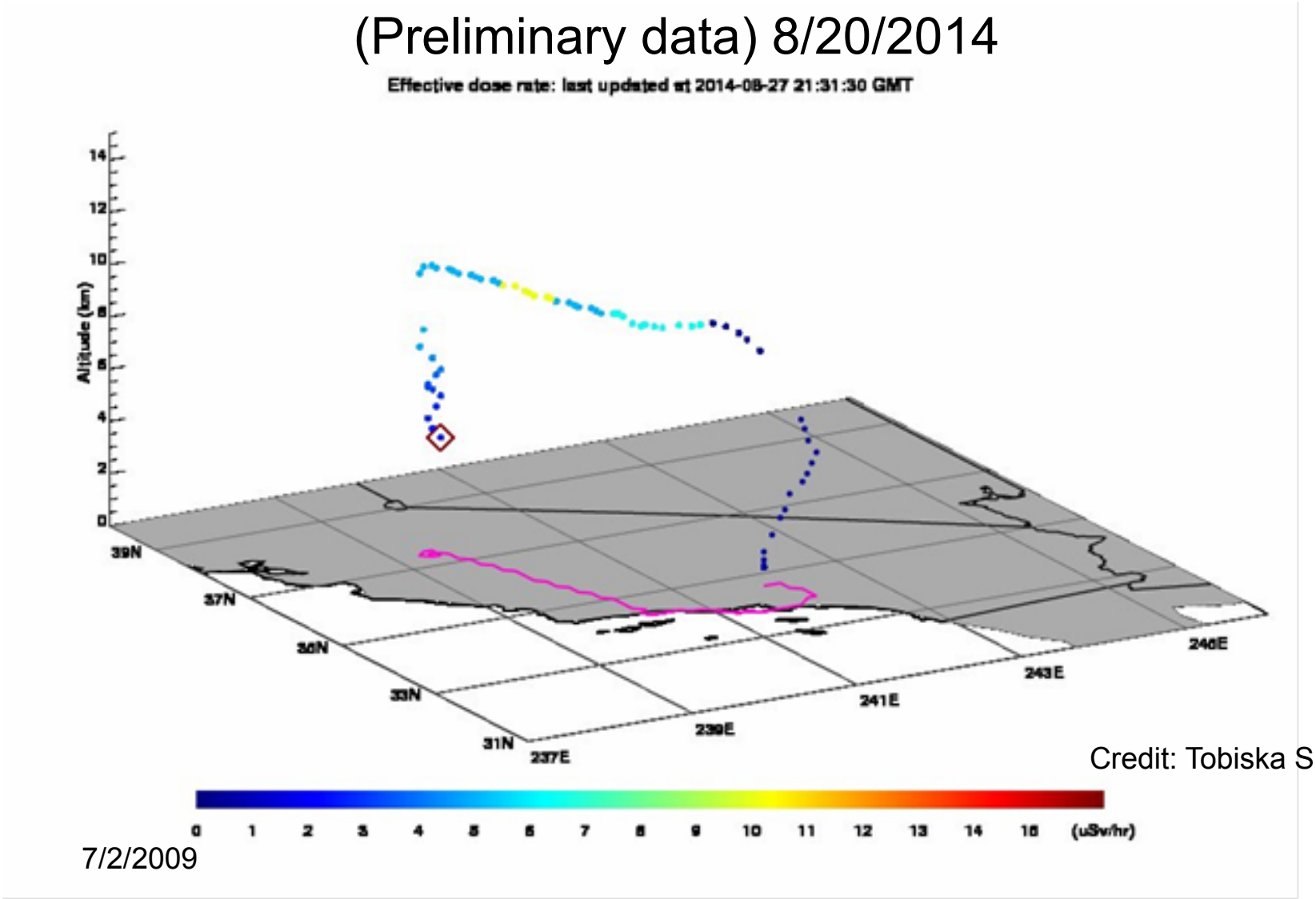
Silicone based dosimeter
Data telemetered via Iridium to LaRC/SET
LaRC uses data to verify NAIRAS model
15 min data latency to smartphone app



SPACE ENVIRONMENT TECHNOLOGIES

Space Research *Space Operations* *Space Standards*

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



Credit: Tobiska SET

7/2/2009

SOFIA missions: Long duration, High Altitude/Latitude, Southern Hemisphere, All Night Flights, Aurora, Radiation Concerns?

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

PRAIRIE VIEW A&M UNIVERSITY
CRESSE
Center for Radiation Engineering and Science for Space Exploration

- 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

- Credit Prairie View A & M

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

- Credit Prairie View A & M

ThermalIzed Neutron MeAsuremeNt Experiment (TINMAN)

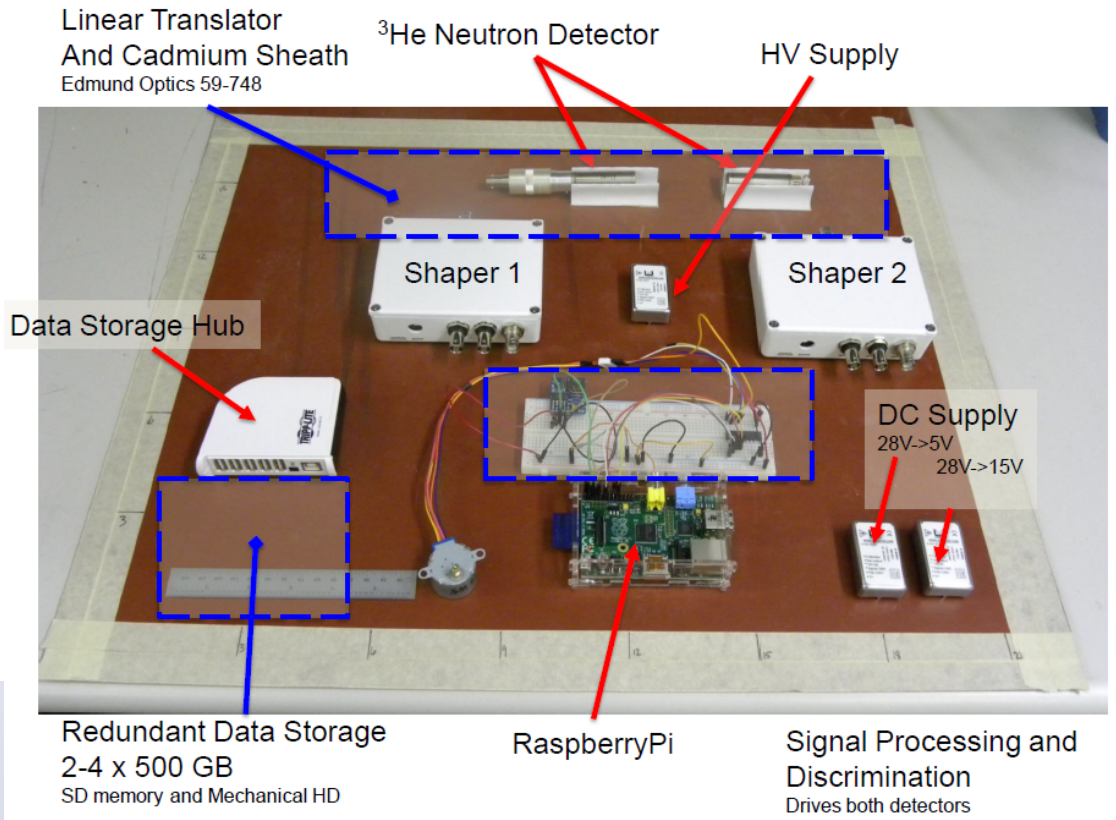
Honeywell

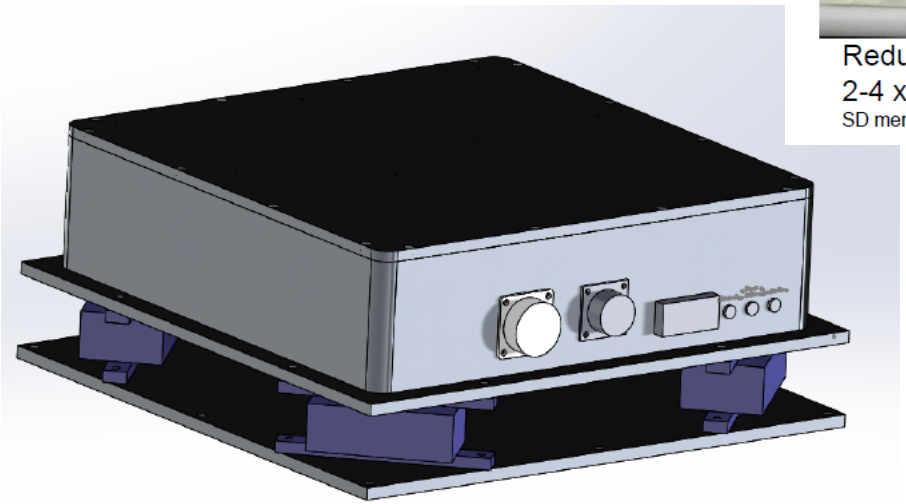
- **Purpose**
  - **Monitor and record the thermal energy neutron environment within various aircraft types and locations.**
    - FL400 is 300X > neutron flux @ sea level
- **Reason**
  - **IC manufacturers using Boron10, ICs more susceptible to thermal energy neutron Single Event Effects (SEEs)-CPU 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

- Credit Honeywell

ThermalIzed Neutron MeAsuremeNt Experiment (TinMan)

Honeywell



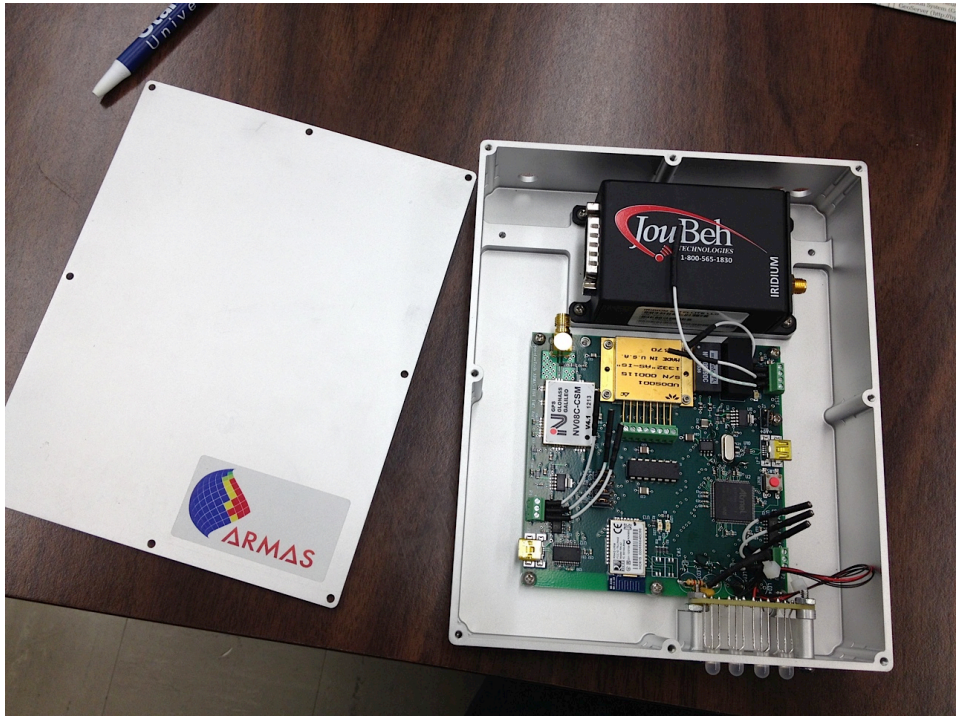


USEWX Phase I 2014

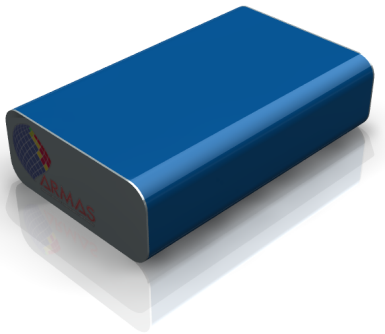
- **A**irborne **R**adiation **M**easurements for **A**erospace **S**afety ARMAS-Lite currently on AFRC DC-8/ER-2
- USEWX SET ARMAS Lite Flight Module (FM)-3 flying and FM-5 in Development
- ARMAS Lite data transmits via Iridium to LaRC for validation of Nowcast of Atmospheric Ionizing Radiation System (NAIRAS LaRC) model
- http://sol.spacenvironment.net/~nairas/

ARMAS-Lite

FM-3



FM-5



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 ER-2, DC-8, GIII, SOFIA B747, F-18, F-15
- Develop inexpensive dosimeters, cross calibrate with Hawk, ARMAS Lite, TinMan
- Integrate inexpensive dosimeters into Radiosondes (AFRC), WX PRANDTL, Rocketsondes, Cubesats
- 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.)

- Polimaster 2165M radiation sensor 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.

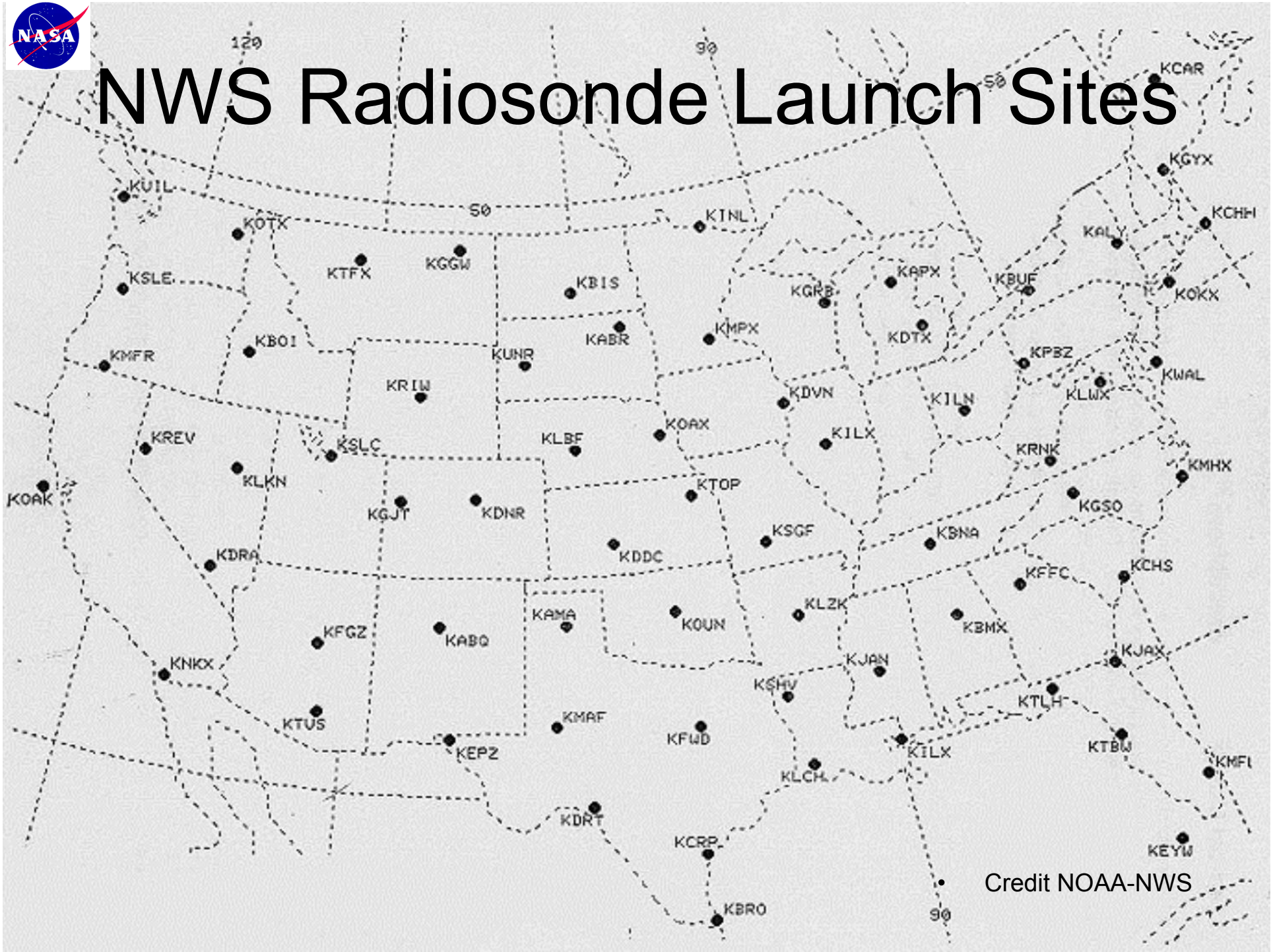
Weather Balloon Launch in support of flight testing

- AFRC Radiosonde equipment
- AFRC Research Instrumentation
- Utilize inexpensive Polimaster X-ray/Gamma radiation sensor
- Flight test dosimeter package with Vaisala Radiosonde and recover payload and data

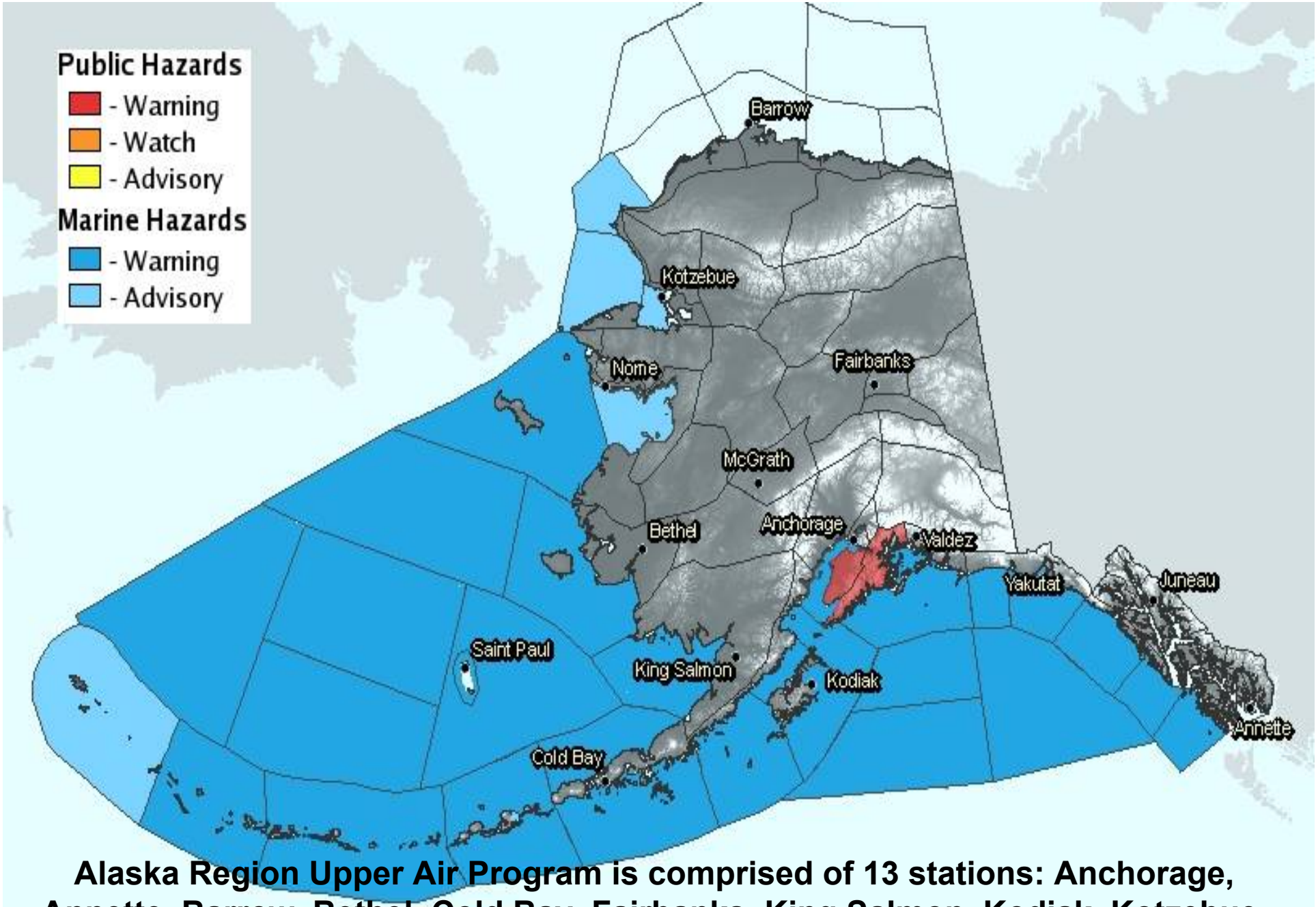
AFRC Radiosondes

- AFRC has Radiosonde experience
- 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
- Potential science payload

NWS Radiosonde Launch Sites

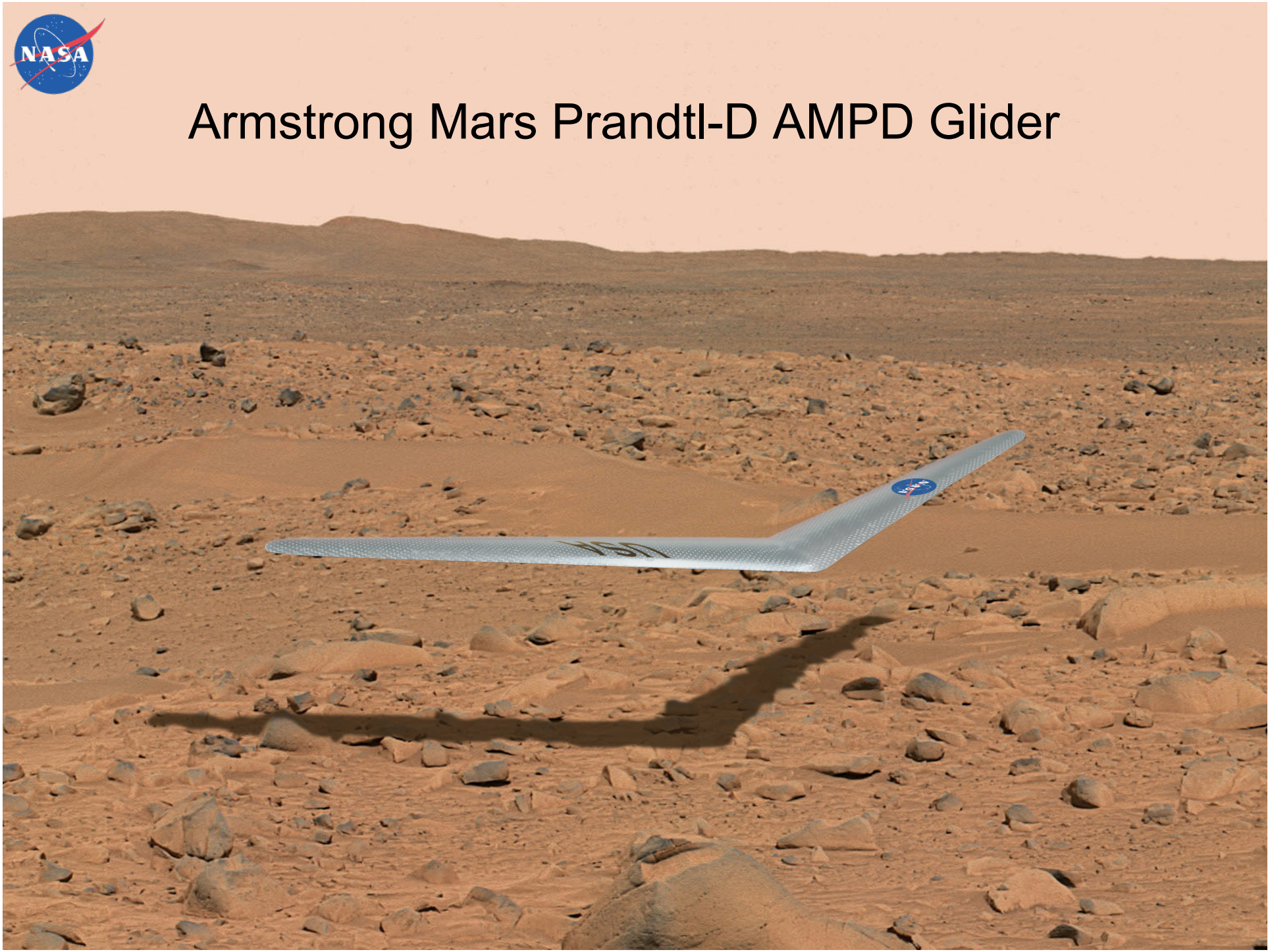


- Credit NOAA-NWS



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. Credit NOAA-NWS

Armstrong Mars Prandtl-D AMPD Glider



PRANDTL
SPACE WEATHER/WEATHER PLATFORM?

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

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Questions?