



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

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

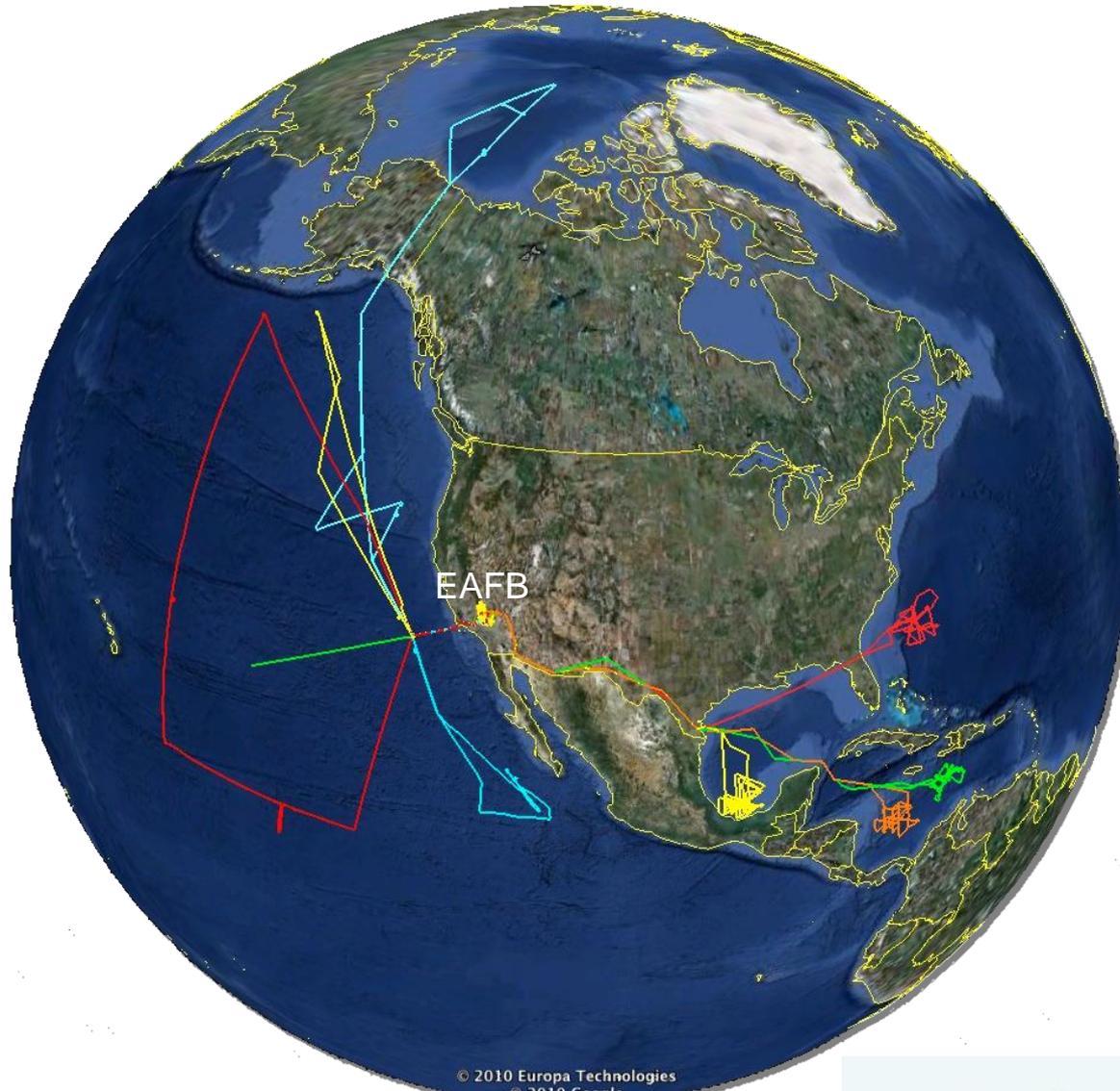
Space Weather and Robotic Mission Operations
Workshop

NASA Goddard Spaceflight Center

September 29-30, 2015



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?



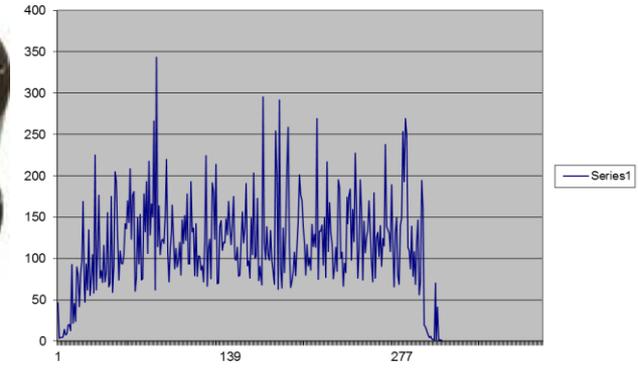


Space Weather Needs at AFRC

- 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 \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

Upper-atmospheric Space and Earth Weather eXperiment USEWX

ARMAS lite, Hawk dosimeter calibration runs, Aug 16, 2014
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>



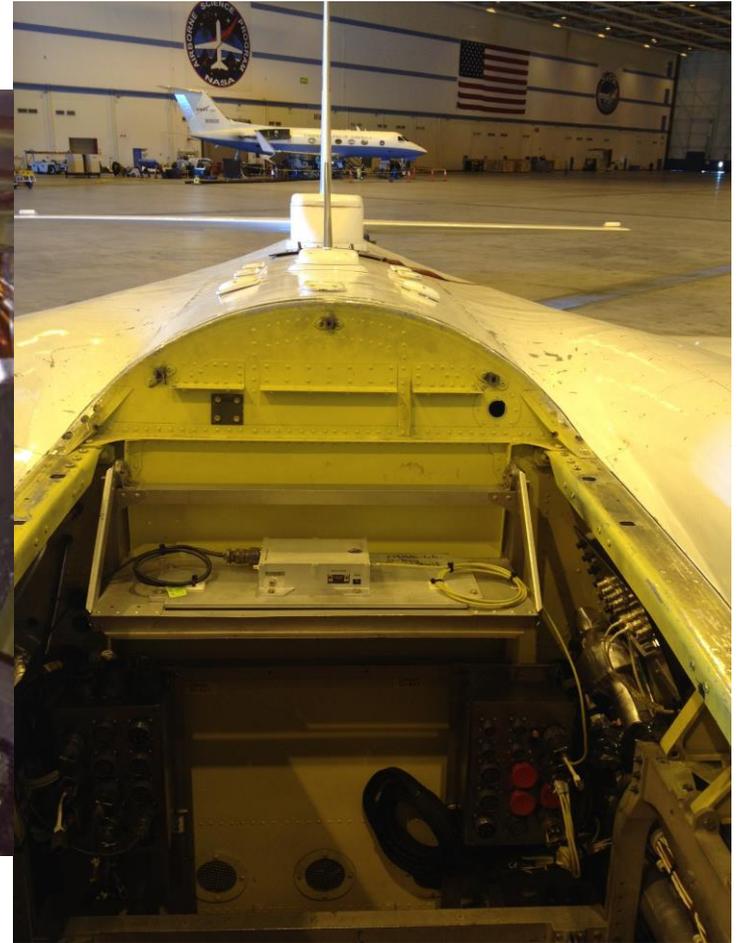
ER-2 superpod



lightning-gamma radiation flashes?

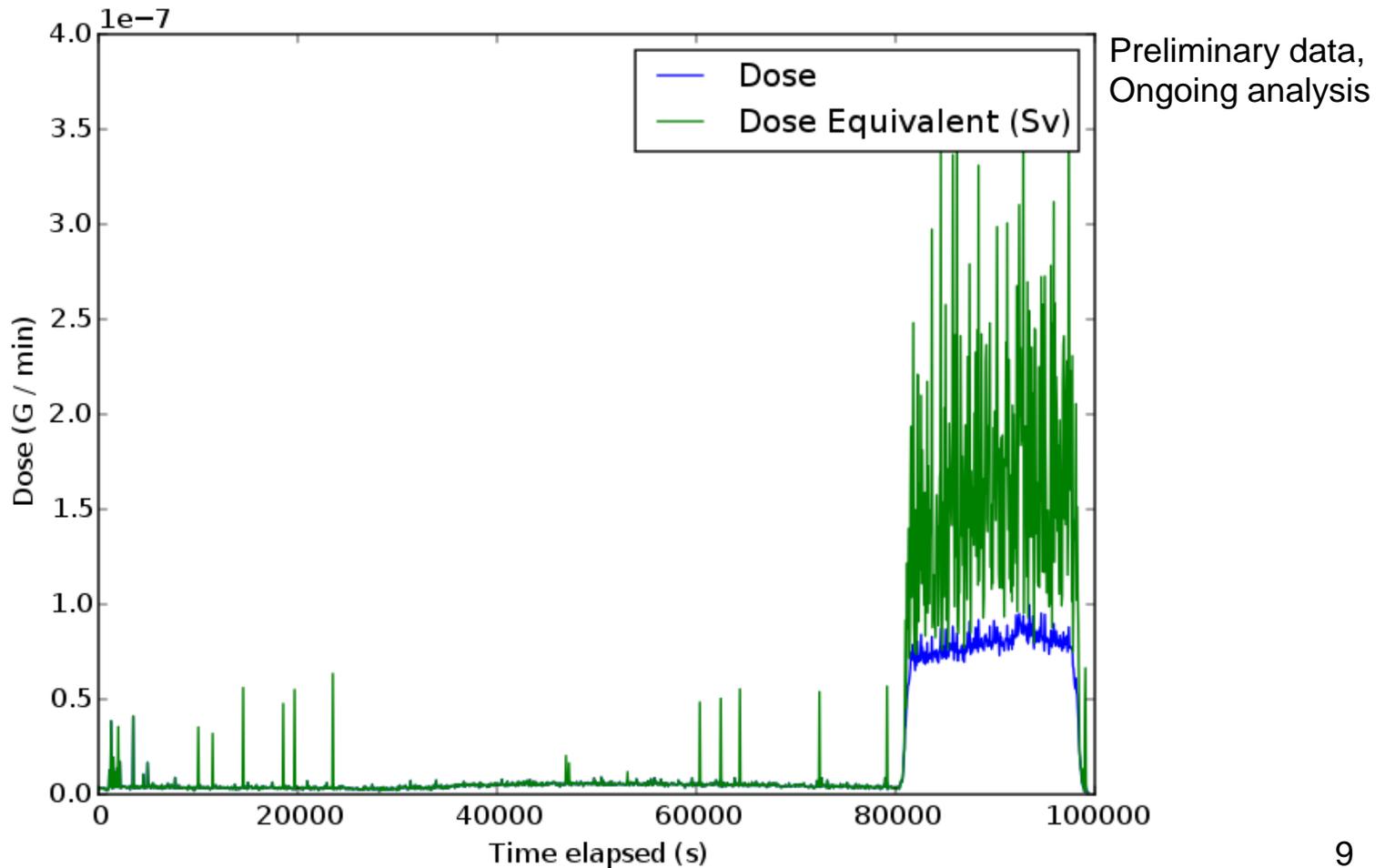


Hawk, TinMan in ER-2 Superpod and ARMAS FM-3 in ER-2 Q-bay



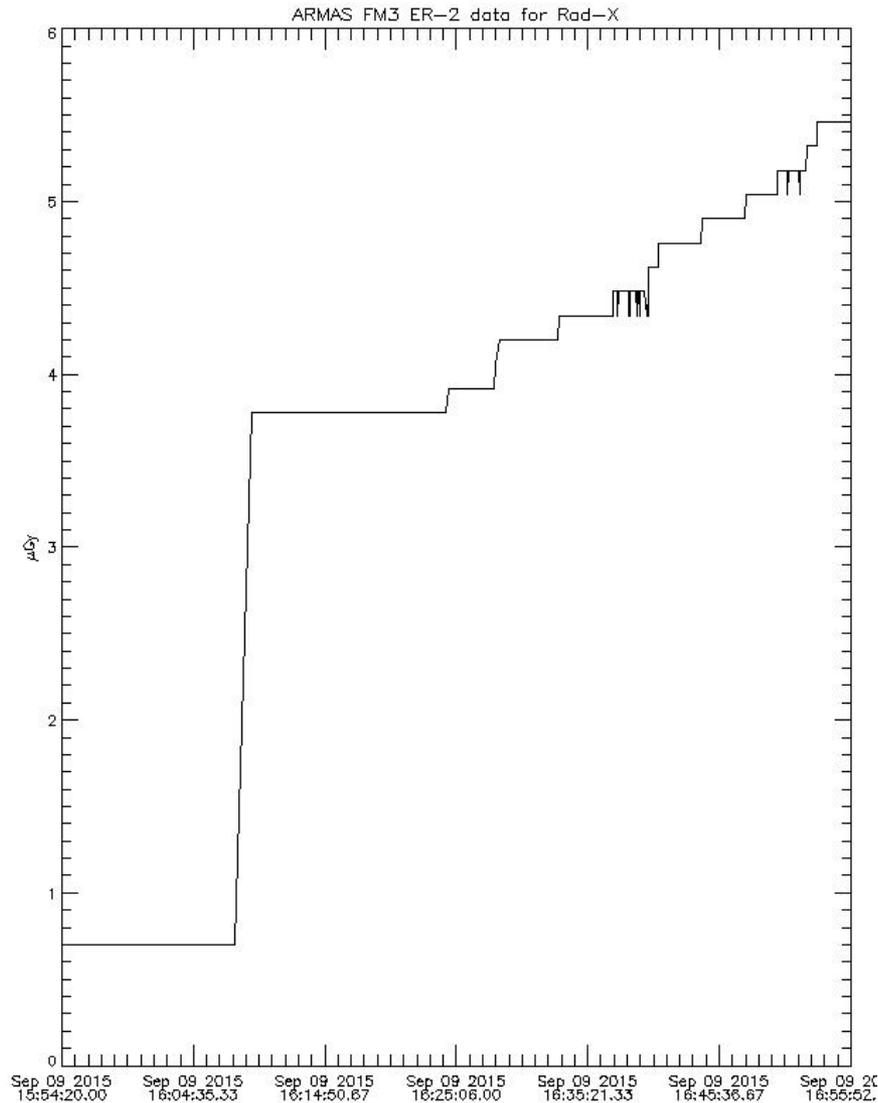


Hawk Dosimeter Data ER-2 on 9-9-2015 for RaD-X





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



Preliminary data,
Ongoing analysis



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/>



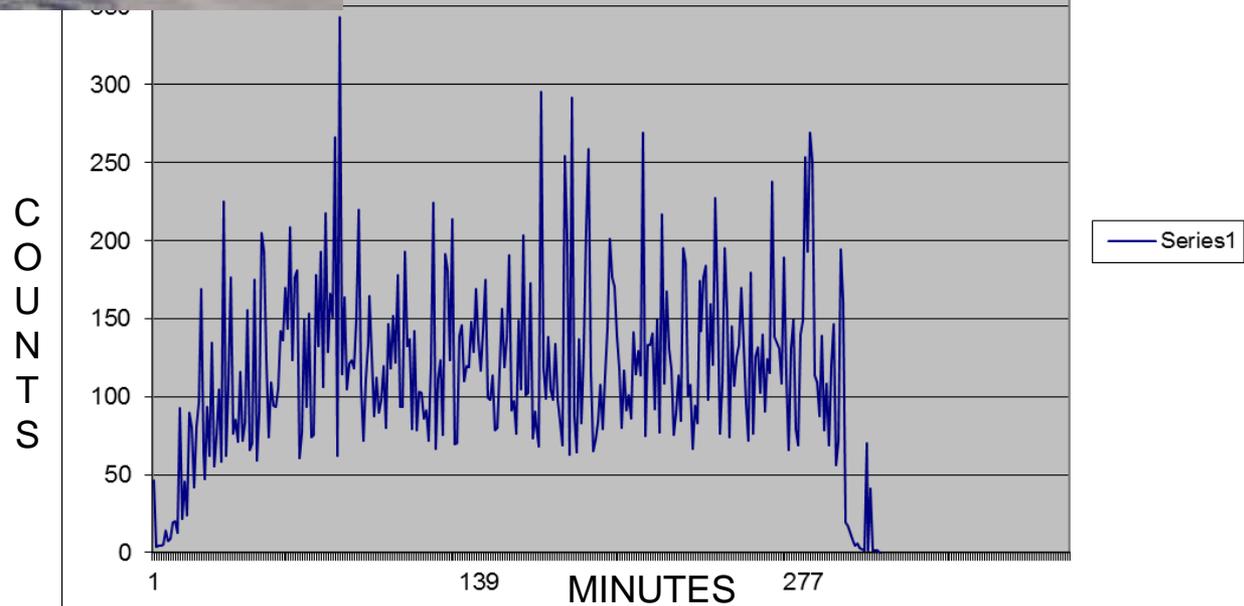




Hawk dose measurements on AFRC C-20 over Iceland



Preliminary data
needing further analysis



SPACE ENVIRONMENT TECHNOLOGIES

Space Research

Space Operations

Space Standards

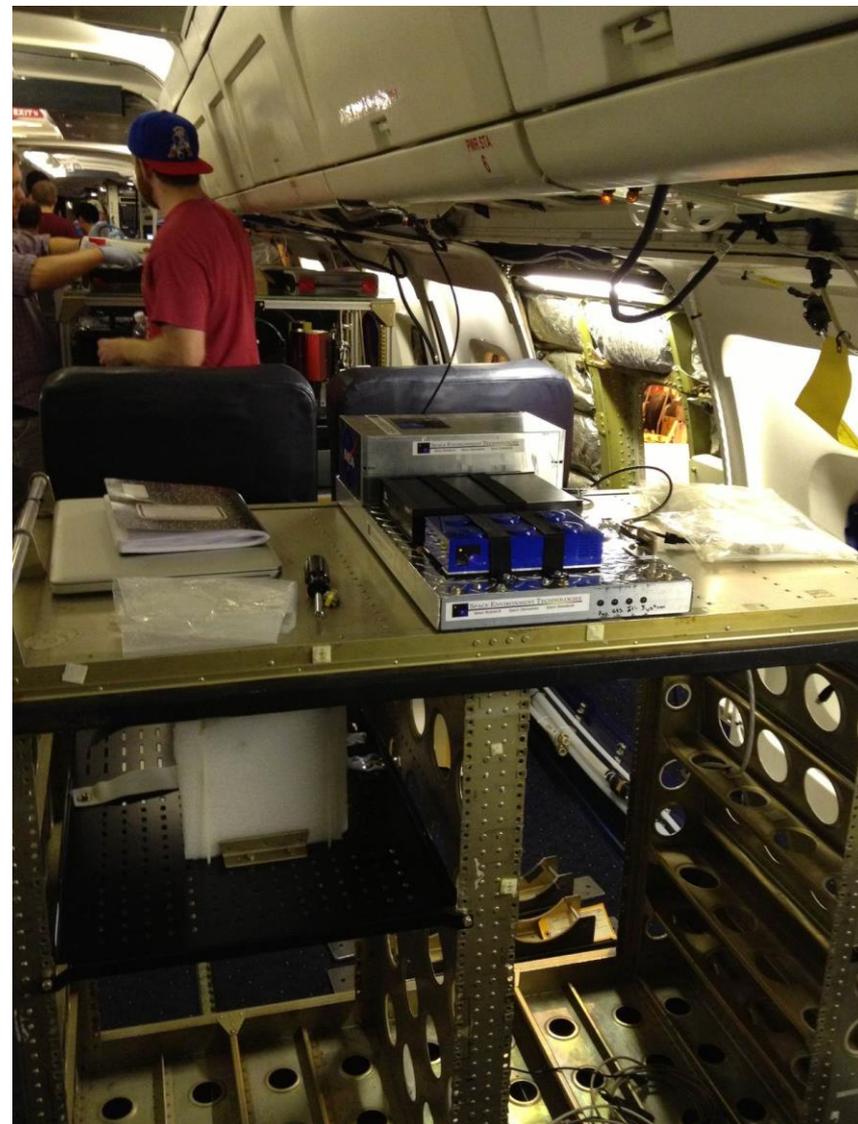
ARMAS-Lite on Rack in DC-8

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

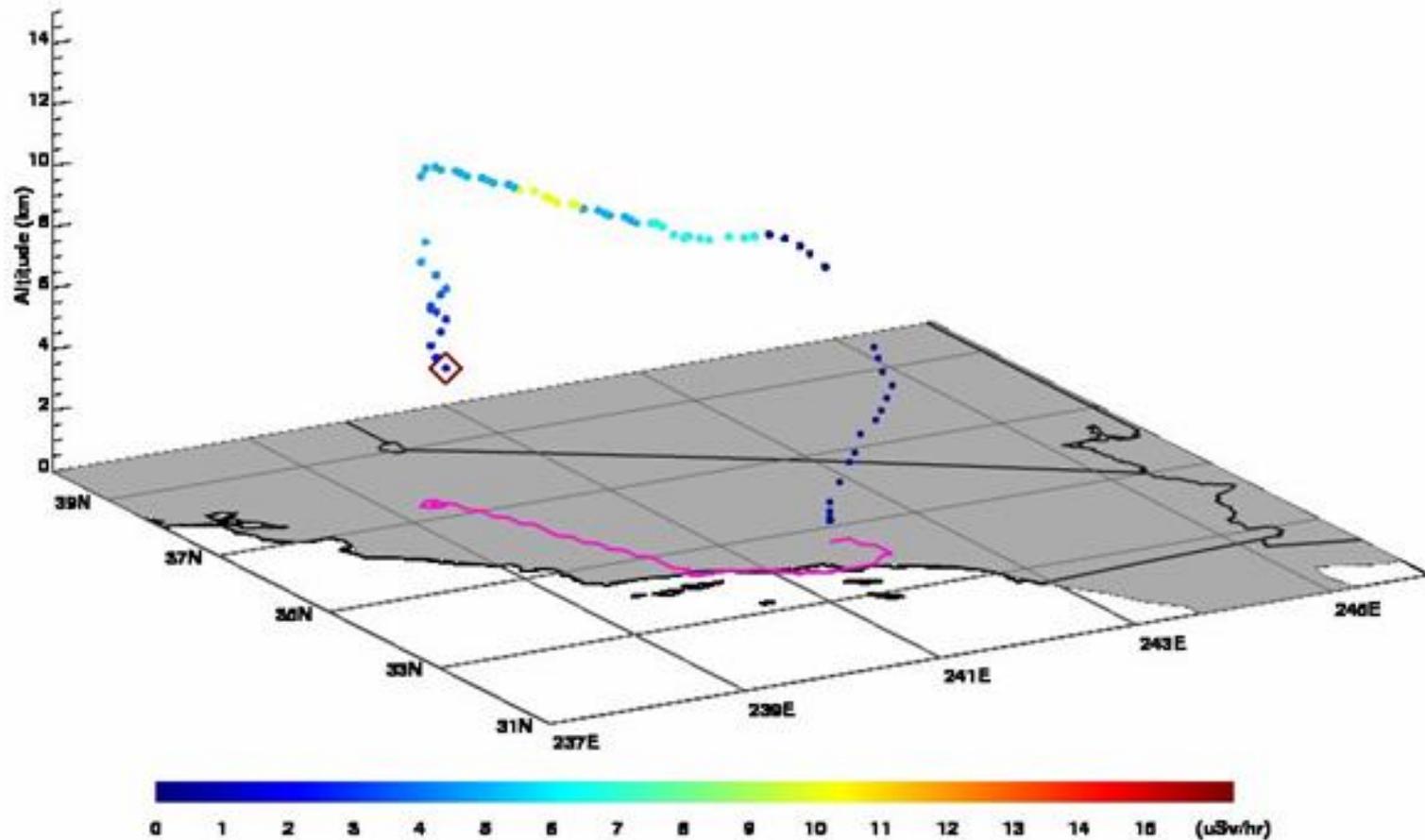
Space Research

Space Operations

Space Standards

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

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



7/2/2009



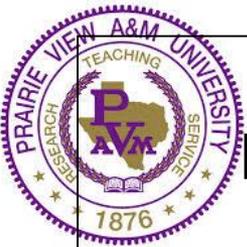
SOFIA missions: Long duration, High Altitude/Latitude, Southern Hemisphere, All Night Flights, Aurora, Radiation Concerns?





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



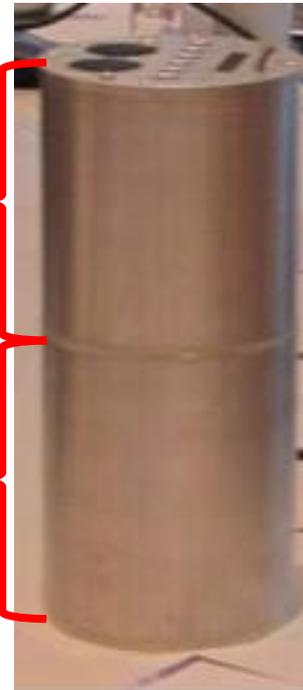
Far West Hawk TEPC Dosimeter

- **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





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**



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

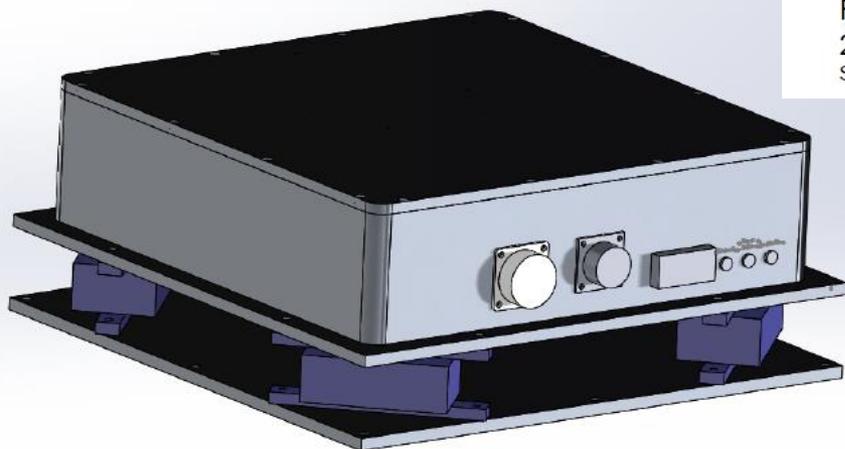
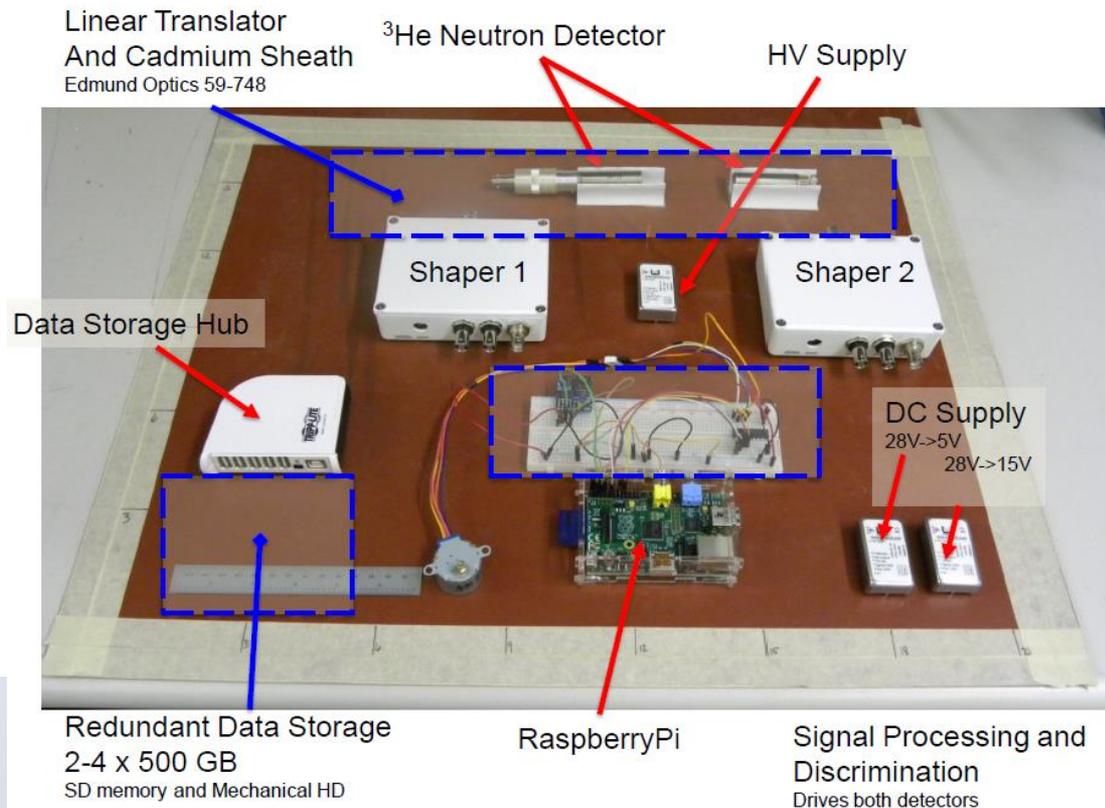
- **Aviation trending toward:**

- 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

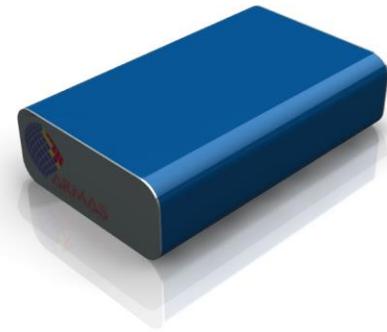
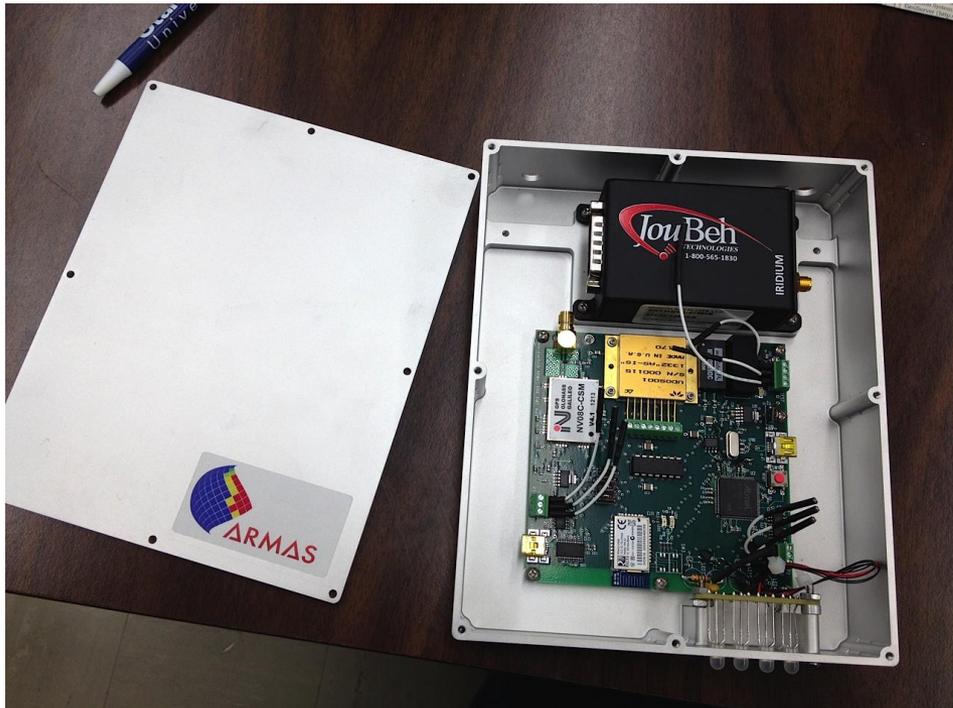
- **Airborne Radiation Measurements for Aerospace Safety** ARMAS-Lite currently on AFRC DC-8/ER-2
- USEWX SET ARMAS Lite Flight Module (FM)-3 flying and FM-5 in Development
- ARMAS Lite data transmits via Iridium to LaRC for validation of Nowcast of Atmospheric Ionizing Radiation System (NAIRAS LaRC) 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



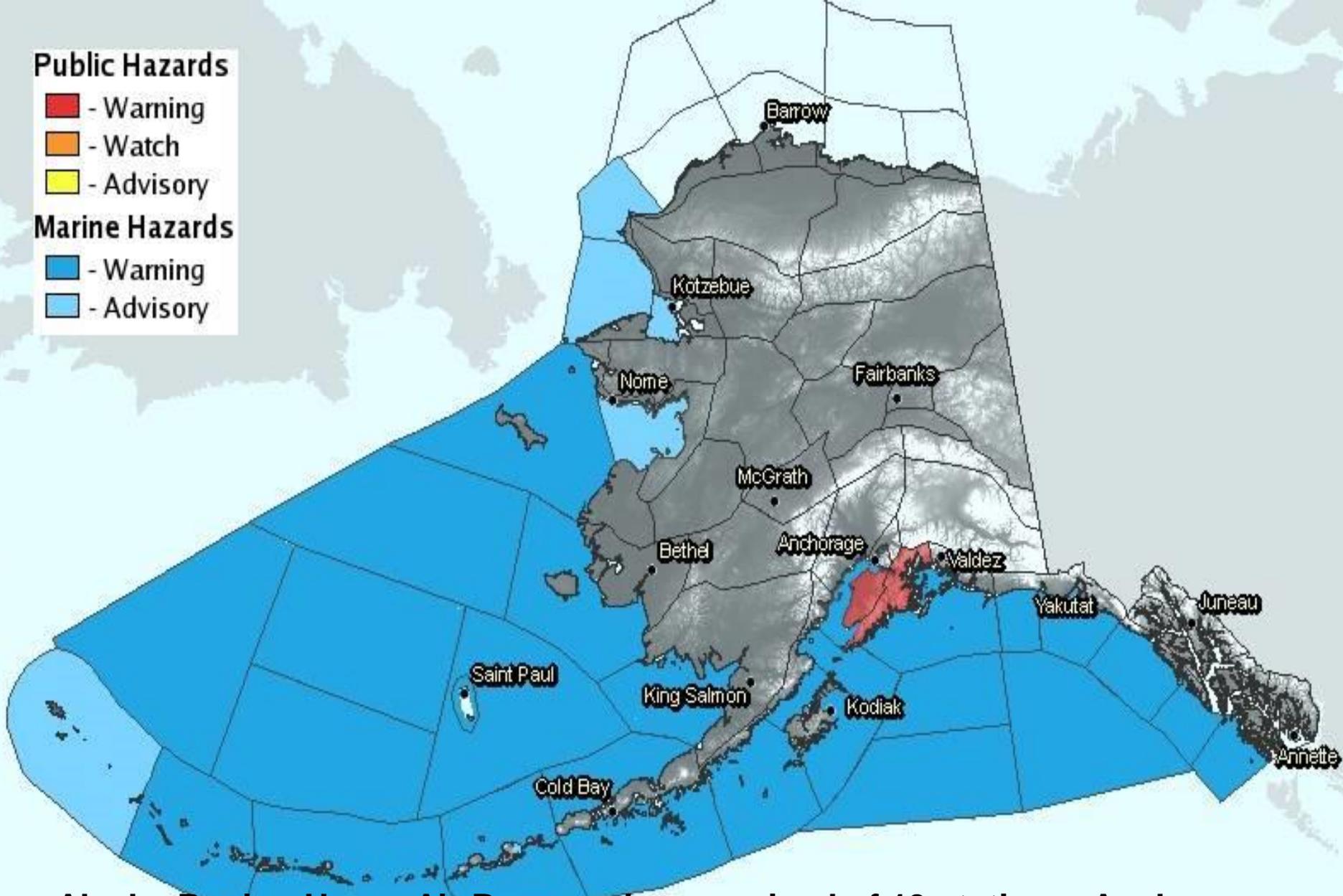
- AFRC has Radiosonde experience
- Coordinate with TIS/STEM to bring dosimeters to NWS offices for a coordinated flight on space weather day of interest
- Need GSFC to assist with forecasting SWPC/GSFC
- Potential science payload

Public Hazards

- Red - Warning
- Orange - Watch
- Yellow - Advisory

Marine Hazards

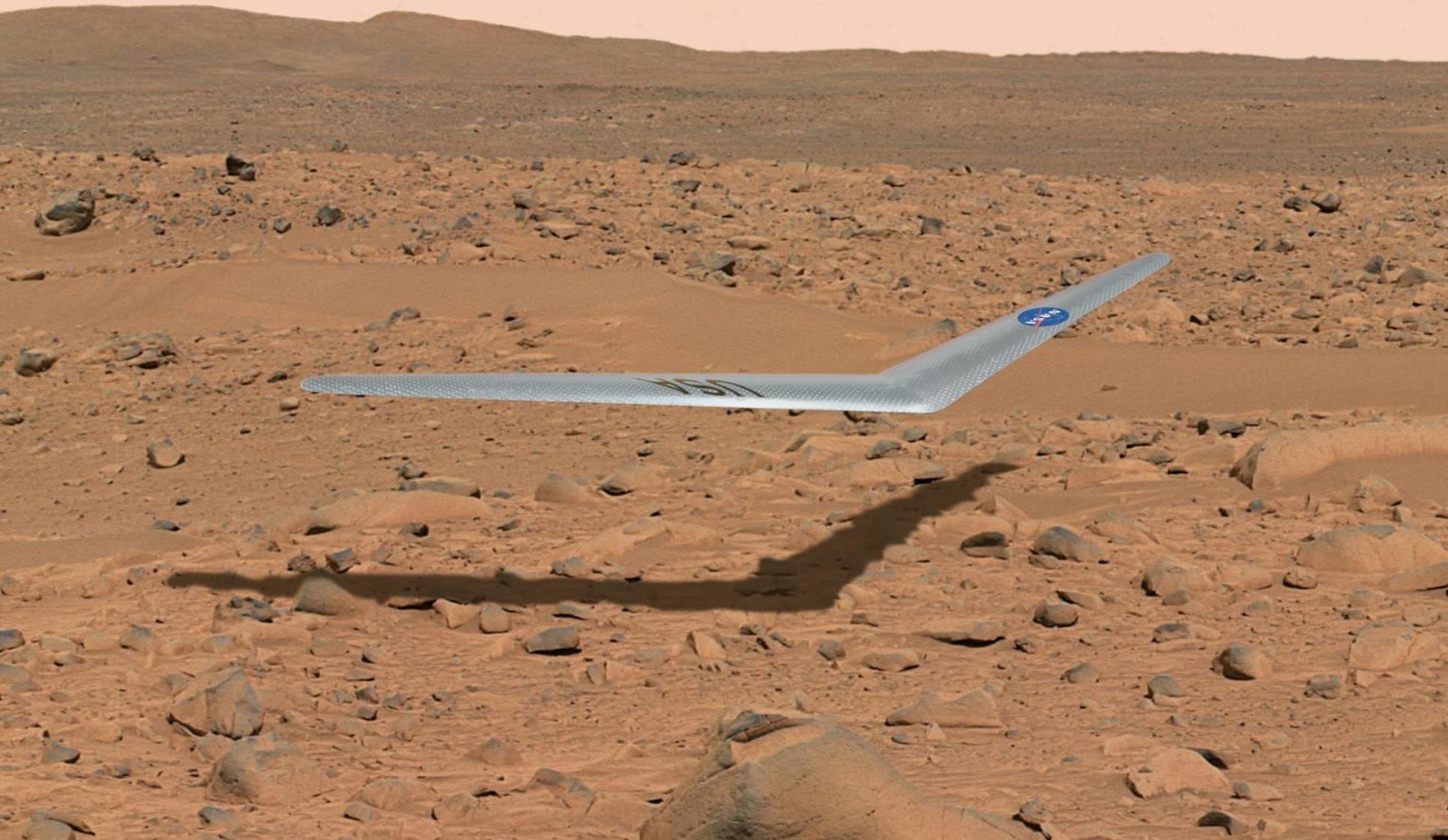
- Dark Blue - Warning
- Light Blue - Advisory



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

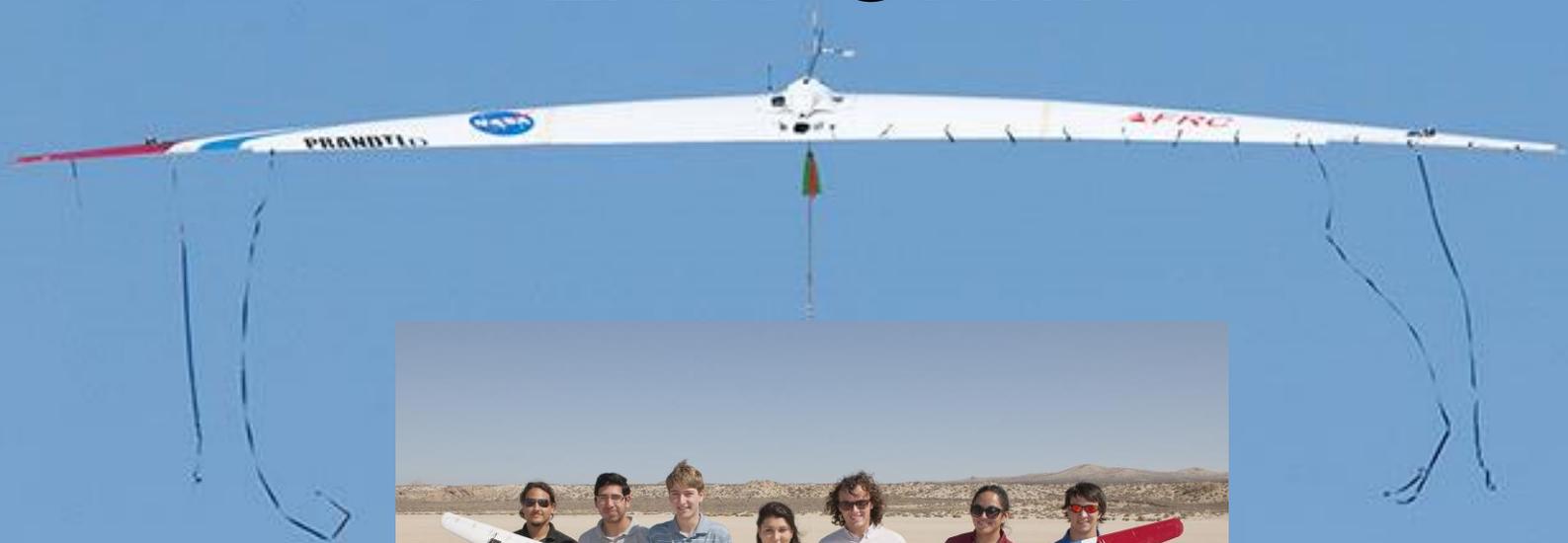


Armstrong Mars Prandtl-D AMPD Glider





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?