ARMAS FM5 SPECIFICATION SHEET

Product name	**ARMAS Flight Module 5 (FM5003 and FM5004)**		
Product purpose	**Radiation Detection Instrumentation for Aircraft**		
Product reference	**http://sol.spacenvironment.net/~ARMAS/index.html**		
Date	**1 June 2019**	Manufacturer	**Space Environment Technologies**

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2	Added FM Operation section	4	WKT	Jun 01, 2016
3	Describe Iridium and BT use	4	WKT	Sep 11, 2016
4	Updated battery charging discussion	4	WKT	Sep 15, 2016
5	Updated typical product and data stream section	9	WKT	Mar 21, 2017
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10	Updated operating temperatures, BT, micro SD & LEDs FM5 internal photo & example data stream plot	3 8, 9	WKT	Jan 17, 2019
11	Updated DC/DC power converter descriptions	2, 3, 4	WKT	Feb 03, 2019

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Contact information:
W. Kent Tobiska, President and Chief Scientist
Space Environment Technologies
1676 Palisades Dr., Pacific Palisades, CA 90272
+1-310-573-4185 (office); +1-310-454-9665 (fax)
ktobiska@spacenvironment.net
http://spacewx.com

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ARMAS
Automated Radiation Measurements for Aviation Safety

ARMAS FM5 Product

PURPOSE

The ARMAS (Automated Radiation Measurements for Aerospace Safety) Flight Module 5 (FM5) system is designed to measure the total ionizing dose of radiation related to human tissue exposure within aircraft environments from:

i. Long-term exposure to background radiation from galactic cosmic rays (GCRs) that can lead to increased statistical risk for cancer-related illness, lifestyle degradation, and death;

ii. Short-term exposure from solar energetic particles (SEPs) during extremely large solar flares that can lead to increased deterministic risk for radiation sickness and death; and

iii. Short-term exposure from energetic electron precipitation (EEPs) during any geomagnetically disturbed condition that can lead to increased statistical risk for cancer-related illness.

DESCRIPTION

The ARMAS Flight Module 5 (FM5) system consists of two components:

i. **Flight instrument**: The FM5 flight instrument provides real-time dosimetric measurements of the radiation environment from aircraft. Radiation dose is created by the penetration of GCRs (p^+, α, Fe^+), SEPs (p^+), and EEPs (e^-) and into the Earth's atmosphere that subsequently interact with neutral species (N_2, O_2) to create secondary and tertiary particles (n, p^+, e^-, α, β, μ, π, γ-rays). Measurements are made using the Teledyne micro dosimeter (μDos) UDOS001 in combination with a GPS chip, an Iridium transceiver, a Bluetooth chip, a micro SD data logger, a microprocessor, and an input for power from a battery, AC/DC, or DC/DC power converter. All these are mated to a printed circuit board and provide the current absorbed dose in Silicon radiation environment within the aircraft via an active Iridium satellite link or Bluetooth pairing to a computer.

ii. **Calibrated data stream**:

   a. The 10-second real-time data are made instantaneously available via Iridium or Bluetooth connection (if activated) to a display of the current tissue-relevant dose and dose rate inside the aircraft. If Bluetooth is used, a serial terminal window application is required on the computer. If no real-time access is available, data is logged to a micro SD card in the unit.

   b. When real-time data packets are enabled five 10-second are downlinked every 50-seconds via Iridium short data bursts or via Bluetooth connection. Iridium data are processed on ground servers and are then compared with the NASA NAIRAS (Nowcast of Atmospheric Ionizing Radiation System) global radiation climatology absorbed dose in Silicon or effective dose. A specification for the most recent hour is provided for tissue-relevant effective dose total value and dose rates for global and regional areas, including those outside the local flight region. Data from the global radiation environment is accessible with an approximate 5–minute latency on the ARMAS web site.

ARMAS FM5 is packaged in a rugged housing constructed from milled aluminum and is designed for use on jet class aircraft. The FM5 unit does not need to be physically attached to the aircraft. It operates with its own rechargeable power supply; serial cables can connect to aircraft GPS and Iridium antennas.

Relevant URLs:

ARMAS: http://sol.spacenvironment.net/~ARMAS/index.html

NAIRAS: http://sol.spacenvironment.net/~nairas/index.html

GENERAL SPECIFICATIONS

Checkpoint	Requirement	Notes
FAA compliance	Non-intrusive compatibility with FAA instrumentation requirements.	FM5 is a small, self-contained unit for carry-on or for qualified attachment per operator/FAA agreements.
Aircraft flight instrumentation	Body and cover: March 2015 FM5A and FM5B were nylon (3D printed); July 2017 FM5C and FM5D are milled aluminum	The ARMAS FM5A and B flight units were initially enclosed in a blue 3D printed nylon case. However, these units were refurbished starting with the transition of FM5A to FM5C and FM5B to FM5D with a milled aluminum case.
GPS connectivity	SMA serial cable connection to aircraft GPS	Active L1 band.
Iridium connectivity	SMA serial cable connection to aircraft Iridium	SBD Iridium with a unique IMEI (FM5003 [A/C]: 300434061503440; FM5004 [B/D]: 300434061501440).
Data logging	Micro SD card data logger	Data is stored automatically whenever the unit is powered on. When it is turned off, the data file is closed and a new file is opened at the next power on. Micro SD card holds 16 GB.
Bluetooth connectivity	Bluetooth pairing	~~100-meter class Bluetooth (user selected active or inactive;~~ **default is inactive**).
Power connectivity	Power from rechargeable Lithium ion battery, AC/DC, or DC/DC converter using a Micro USB B connector to the FM5	Power is supplied from one of these modes: 1. a rechargeable 10,000mAh 2-Port USB Lithium ion Power Pack that is compliant with current TSA power thresholds. Typical life is 25 hours without Iridium usage (half that with Iridium). 2. an AC/DC converter. 3. a DC/DC converter.
Micro dosimeter	Teledyne micro dosimeter uDOS001	Commercial grade micro dosimeter; resets to “0” counts whenever the FM5 is powered off or the black μDOS switch is **OFF**.
LEDs	Indicator status lights	Power button (**green** (FM5A/C) or **blue** (FM5B/D) steady: on/off). ~~Bluetooth (**blue** steady: active; **green** blink: waiting to pair) viewable through the left small window.~~ ~~GPS (**green** steady: on; **red** steady: waiting to receive).~~
Temperature	Operating range –15° to +25° C	Teledyne micro dosimeter chip limitation (-30° to +40° C). Microprocessor limitation (–15° to +25° C).
Operations	Easy operations	Whenever the power button is pressed the unit will be on. When power is off, the entire unit is off. The μDOS can be controlled separately with a black μDOS power on/off switch, whose operation does not affect the rest of the instrument power (e.g. GPS or microprocessor).

FM5 DIMENSIONS, MASS, POWER

Checkpoint	Requirement
Overall size	~~FM5A and FM5B: 4.0 x 6.7 x 2.0 inches (10.2 x 17.0 x 5.0 cm)~~ FM5C and FM5D: 4.0 x 6.7 x 1.3 inches (10.2 x 17.0 x 3.4 cm)
Total net weight	~~FM5A and FM5B: 1.1 lb. (0.499 kg)~~ FM5003 [C] and FM5004 [D]: 1.144 lb. (0.519 kg) without battery and cable 1.729 lb. (0.784 kg) including battery and cable
Input/output	60 Hz 120 VAC -> 5 VDC; 5 VDC battery (2.4A)
Adaptor input for recharge cable	5V DC charge from a USB port (variable current but always <1A)
Total power	8.75 W (peak), 2.25 W (average), 1.5 W (standby)

FM OPERATION

GPS Passive operation. ARMAS FM5 does not need to be physically attached to the aircraft. It can operate passively (no Iridium output with internal J8 and J10 jumpers on "RS") as a carry-on item on commercial flights. Since there is often RFI in commercial airports, a successful method of operation has been to turn on the instrument (big button) before boarding while in the passenger waiting area. Once on the aircraft and before takeoff, any high dose rates due to RFI that have been accumulated can be zeroed by turning off the black micro dosimeter switch for a few seconds, then turning it on again (do not power on/off the entire instrument). This resets the μDOS values to zero. FM5 is best stored in the overhead luggage bin above the user's passenger seat. A standalone GPS antenna can be attached for retrieving GPS information intermittently during the flight. Typically a GPS antenna attached to the internal window of an aircraft provides very good data. In addition, following a commercial flight, the FlightAware flight log (in UTC time) can be downloaded to preserve the flight time and location information for integration with the FM5 data record.

GPS Active operation. The ARMAS FM5 instrument can be operated actively (Iridium output) where both Iridium and GPS serial cables can be attached to the unit. Iridium data transmit requires the internal J8 and J10 jumpers to be in the "BT" configuration, which also enable Bluetooth transmission. The Iridium link enables real-time telemetry to the ground. The instrument can operate with no Iridium and no Bluetooth but with GPS connected. Capture of GPS data use removes the need for retrieving FlightAware data.

Battery charging.

A. FM5A/C and FM5B/D operate with their own rechargeable **internal** power supply. The Lithium-ion polymer battery is sized to be approximately half the power allowed by TSA. For safe operations, the battery charging procedure is the following:
   1) charge the battery with an AC adaptor and micro USB connector
   2) charge in an environment of 0–40° C (the cabin is typically in the range of 15–25° C)
   3) do not charge the battery when the plane is generally unattended
   4) the COTS battery container is properly constrained from excess vibration and is not damaged
   5) leave the micro USB PLUGGED IN during pre-flight activities to charge the battery
   6) POWER ON the micro USB but with ARMAS FM5 powered OFF (push button light off)
   7) Approximately 15 minutes prior to takeoff UNPLUG the micro USB connector to the battery
   8) TURN ON the ARMAS FM5 (push button light on)
   9) ARMAS FM5 operates normally during the flight (no other attention needed)
   10) TURN OFF ARMAS FM5 after landing and ensure micro USB connector is UNPLUGGED

   This procedure enables pre-flight recharging under supervision and avoids operating the instrument while the battery is charging. The concern is to overcharge the battery, which may cause battery failure, overheating, fire, or explosion.

No longer available

B. FM5C and FM5D operate with:
   - their own rechargeable **external** power supply: Schneider Electric APC model M10 10,000mAh (37 Wh) 2-Port USB Power Pack (Black – MFR #1ICP5/80/113-2) Lithium-ion polymer battery sized to be approximately half the power allowed by TSA using the same battery charging procedure as noted in (A) above. Use 2.4 A USB output port;
   - 60Hz 110-120 VAC to 5 VDC power converter;
   - >18 VDC to 5 VDC power converter.

FM CALIBRATION TESTS

Test name	Test description & expected result	Notes
Altitude validation	Range variation nominal	50–13100 meters
Latitude validation	Range variation nominal	20–50° N
Pressure validation	Nominal cabin pressure (12,000 ft.)	–
Fe^{+} ion validation	NASA Space Radiation Laboratory (NSRL) beam line test positive	>12 Rads
neutron validation	Los Alamos Neutron Science Center beam line test positive	>200 Rads
proton validation	Loma Linda University Medical Center beam line test positive	>6 Rads

µDos name	Heavy ion (Fe) TID (NSRL)	Neutron TID (LANSCE)	Proton TID (LLUMC)	gamma-Ray TID (LANSCE)	airplane shielding (Fe-NSRL)	airplane shielding (n-LANSCE)	airplane shielding (p-LLUMC)	long exposure stability (LANSCE)	beam collimation (LANSCE)	cross compare consistency	repeatability power cycle (DC-8)
	Rad	Rad	Rad	Rad Rad n^{-1}	Rad	Rad Rad n^{-1}	Rad	Rad Rad n^{-1}	Rad	Rad Rad n^{-1}	# of flights
SUNSET	12.18	154.34	4.31	4.55 1.0e-09	4.89	3.52 1.4e-09	1.70	38.87 1.3e-09	22.94	3.46 1.5e-09	29
TOPANGA	–	48.05	0.99	–	10.58	10.58 1.8e-09	–	28.38 1.3e-09	5.68	3.41 1.6e-09	0
MALIBU	–	38.23	1.79	–	4.26	4.26 1.8e-09	0.81	29.06 1.2e-09	0.29	4.32 1.9e-09	0

FM5A and FMB EXTERNAL

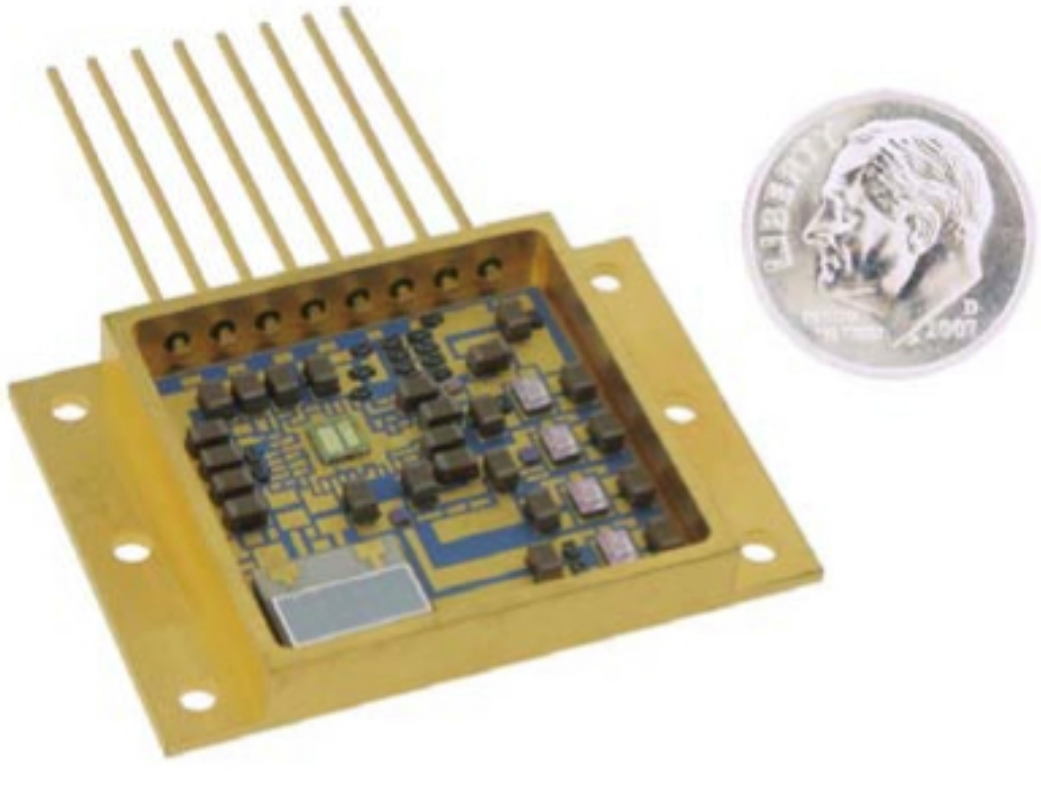
FM5A & B external (top and front)	

FM5C and FMD EXTERNAL

FM5C & D external (top and front)	

FM5A & B external (rear)		
FM5C & D external (rear)		

FM5 INTERNAL

Printed circuit board with micro dosimeter, GPS, Bluetooth, Iridium, microprocessor, and battery (photo)	
Teledyne micro dosimeter (μDOS)	

DATA STREAM

Data interface	Functionality
ARMAS web site	a) Global and regional tissue relevant situational awareness via internet connection b) Archival database c) http://sol.spacenvironment.net/~ARMAS/index.html
Typical data product for one flight (top panel is effective dose rate and D-index vs. time; bottom panel is the geographical context for the flight effective dose in 3D graphical format, shown in conjunction with a graphical context of the incident protons due to the GCRs)