

Progress Towards MIRA: The new CARI-7 and ESRA

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**Federal Aviation
Administration**



FAA Models for Cosmic Radiation Exposure

**Galactic Cosmic Radiation:
CARI (1958-Present)**

Solar Cosmic Radiation:

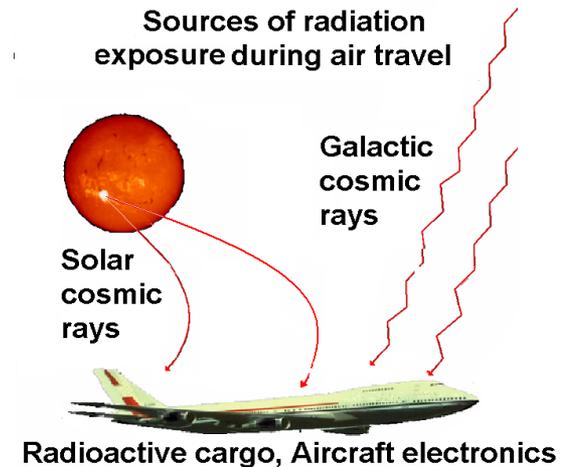
- **Solar Radiation Alert System (SRAS)
for real-time evaluation**
- ***Ad hoc* codes for more precise
after-the-fact evaluations**



What is CARI?

(The old acronym for CAMI)

- The first CARI program was released in the early 1990's.
- PC computer software for calculating the dose of galactic cosmic radiation (GCR) received on flights.
- Used by pilots and airlines worldwide to monitor career GCR radiation doses.
- Used by epidemiologists to estimate past GCR exposures for radiation effects studies.



Progress in CARI

CARI-6:

- Dose rates pre-calculated by LUIN,
- Excellent for commercial aviation but limited by superposition approximation. Increasingly inaccurate if altitude is above 60,000 ft.

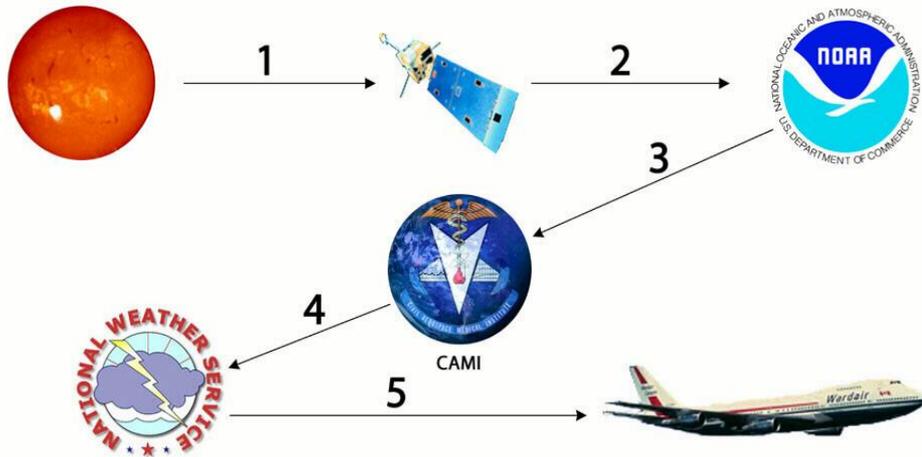


CARI-7 (in validation phase)

- Dose rates derived from MCNPX simulations of cosmic ray showers.
- Superposition approximation is not an issue.
- Accurate effective dose rates possible to the edge of space.
- To be released in Fortran and .NET formats



SOLAR RADIATION ALERT SYSTEM



1. An eruption on the sun raises radiation levels in the earth's environment.
2. A GOES satellite measures the radiation and transmits the data to NOAA.
3. A CAMI computer obtains and analyzes the data from NOAA.
4. CAMI issues any needed alert or update to the National Weather Service.
5. The National Weather Service informs the aviation community.

(a) The Advanced Weather Interactive Processing System (AWIPS) identifier is ALTPAV.

(b) The Space Weather Message Code is ALTPAV.

(c) The World Meteorological Organization (WMO) header is WOXX50 KWNP.

weather.noaa.gov/pub/data/raw/wo/woxx50.kwnp.alt.pav.txt

Enhanced Solar Radiation Alerts (ESRA)

Will be based on new MCNPX 270 proton and alpha showers

Will incorporate corrected P11 interpretation

Will include neutron monitor data for estimates of global anisotropy

Will provide both older text alerts through NWS and graphical output available from the WWW



MCNPX

What is it? Monte Carlo N-Particle eXtended

A general purpose radiation transport code that uses Monte Carlo techniques developed at Los Alamos National Laboratory

Both CARI and ESRA will now be based on the same set of Monte Carlo shower data calculated by MCNPX 2.7.0.

Only the primary spectrum generation will be different:
CARI-7 from Badhwar and O'Neill 2011 GCR
ESRA from GOES and neutron monitors



Using MCNPX

MCNPX is used to simulate cosmic ray showers for neutrons and ions H-Fe.

Flux tallies are made throughout the atmosphere approximately every 3 km through 33 km, then more sparsely up to 100 km.

Tallies include n, e, gamma, pi, mu, p, d($^2\text{H}^+$), t($^3\text{H}^+$), alpha, ^3He , and fully ionized Li-Fe.

Tally spectral energy range is 1MeV-1TeV for all particles, with added low-energy tallies for neutron and gamma spectra.



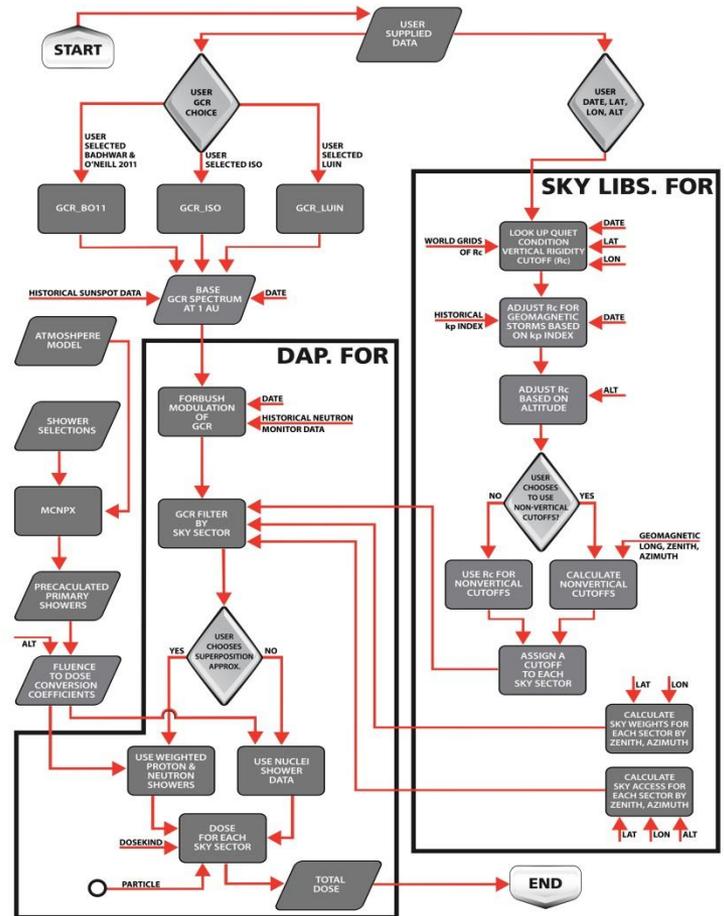
After MCNPX . . .

...anything calculable from the shower data can be extracted (with enough effort)

FOR CARI-7 and SRAS: Shower data are reduced to dose rates at each tally altitude per unit of primary fluence at the top of the atmosphere for each type and energy of primary particle.

Primary particle spectra at the top of the atmosphere are used to guide integration of doses at each altitude for the conditions of the time of the query.

CARI-7 DOSE-AT-POINT PROCESS



CARI-7 vs CARI-6

AIRPORTS Origin – Destination	Highest flight level	In-air hours	Effective dose ^A / mSv		
			CARI-7 E ₁₀₃ , Jan. 2000	CARI-7 E ₆₀ , Jan. 2000	% change from E ₆₀ (CARI-6)
Houston TX – Austin TX	200	0.5	0.19	0.21	23.
Miami FL - Tampa FL	240	0.6	0.41	0.48	23.
St. Louis MO – Tulsa OK	350	0.9	1.41	1.77	4.0
Tampa FL - St. Louis MO	310	2.0	4.06	4.92	4.9
New Orleans LA – San Antonio TX	390	1.2	2.71	3.34	2.8
Los Angeles CA – Honolulu HI	350	5.2	12.2	14.8	1.4
New York NY – San Juan PR	370	3.0	8.12	9.99	0.1
Honolulu HI – Los Angeles CA	400	5.1	13.5	16.5	1.2
Los Angeles CA – Tokyo JP	400	11.7	35.1	43.1	-0.2
Tokyo JP – Los Angeles CA	370	8.8	26.9	33.2	0.0
Washington DC – Los Angeles CA	350	4.7	15.1	18.7	-1.6
New York NY – Chicago IL	390	1.8	6.60	8.29	-6.3
Lisbon PG – New York NY	390	6.5	22.4	27.9	-2.8
London UK – Dallas/Ft. Worth TX	390	9.7	33.2	41.0	-5.5
Seattle WA – Washington DC	370	4.1	16.4	20.6	-7.2
Dallas/Ft.Worth – London UK	370	8.5	29.7	36.9	-6.1
Chicago IL – San Francisco CA	390	3.8	14.7	18.4	-3.6
Seattle WA – Anchorage AK	350	3.4	12.4	15.5	-7.7
San Francisco CA – Chicago IL	410	3.8	15.6	19.6	-4.9
New York NY – Seattle WA	390	4.9	20.2	25.5	-8.3
London UK – New York NY	370	6.8	27.3	34.2	-7.8
New York NY – Tokyo JP	430	13.0	55.1	69.2	-7.5
Tokyo JP – New York NY	410	12.2	50.7	63.7	-7.7
London UK – Los Angeles CA	390	10.5	44.6	56.0	-8.3
Chicago IL – London UK	370	7.3	30.8	38.7	-9.2
London UK – Chicago IL	390	7.8	34.0	42.8	-9.1
Athens GR – New York NY	410	9.4	44.6	56.5	-7.2



More CARI-7 Preliminary Results

Comparison of calculated $H^*(10)$ flight doses with in-flight TEPC measurements from Lewis et al. [2002].

CITY PAIR (ICAO codes)	DATE	CARI-7 $H^*(10)$ dose/ $mSv \cdot h^{-1}$	TEPC dose equivalent/ $mSv \cdot h^{-1}$	CARI-7 % Deviation from TEPC
CYZT-EGVN	2001/02/27	27.2	28.0	-2.86
EGVN-LDZA	2001/02/28	6.52	7.22	-9.65
LDZA-CYTR	2001/03/01	32.5	33.9	-4.13
CYOW-CYFB	2001/03/28	9.47	9.32	1.61
CYFB-CYRB	2001/03/28	4.57	4.30	6.28
CYRB-CYFB	2001/03/28	5.03	4.67	7.71
CYFB-CYOW	2001/03/29	9.53	8.69	9.67
CYTR-CYBG	2001/05/24	2.84	2.67	6.37
CYBG-CYOD	2001/05/24	13.8	12.4	11.3
CYOD-CYTR	2001/05/24	14.8	15.5	-4.52
KJFK-KMIA	2001/06/04	9.85	11.0	-10.5
KMIA-SAEZ	2001/06/05	24.6	15.7	56.7
SAEZ-NZAA	2001/06/06	52.6	55.8	-5.73



Plans - MIRA

Combine ESRA and CARI into one product – Maps of Ionizing Radiation at Altitude (MIRA).

MIRA would combine GOES data, neutron monitor data, and geomagnetic indices to provide past and near-real time estimates of combined solar and galactic cosmic radiation dose rates.

For MIRA data entry

An optional point-and-click on a map, visual flight data input interface for tablet style use

Keep text driven batch mode for multi-route calculations and research needs.

