Sources of Occupational Exposure to Ionizing Radiation for Air and Space Travelers

1 Galactic Cosmic Radiation

2 Energetic Solar-Particle Radiation

3 Radioactive Cargo

4 Radioactive Clouds (Chernoble, Fukishima, etc)

5 Lightning and Transient Gamma Ray Flashes
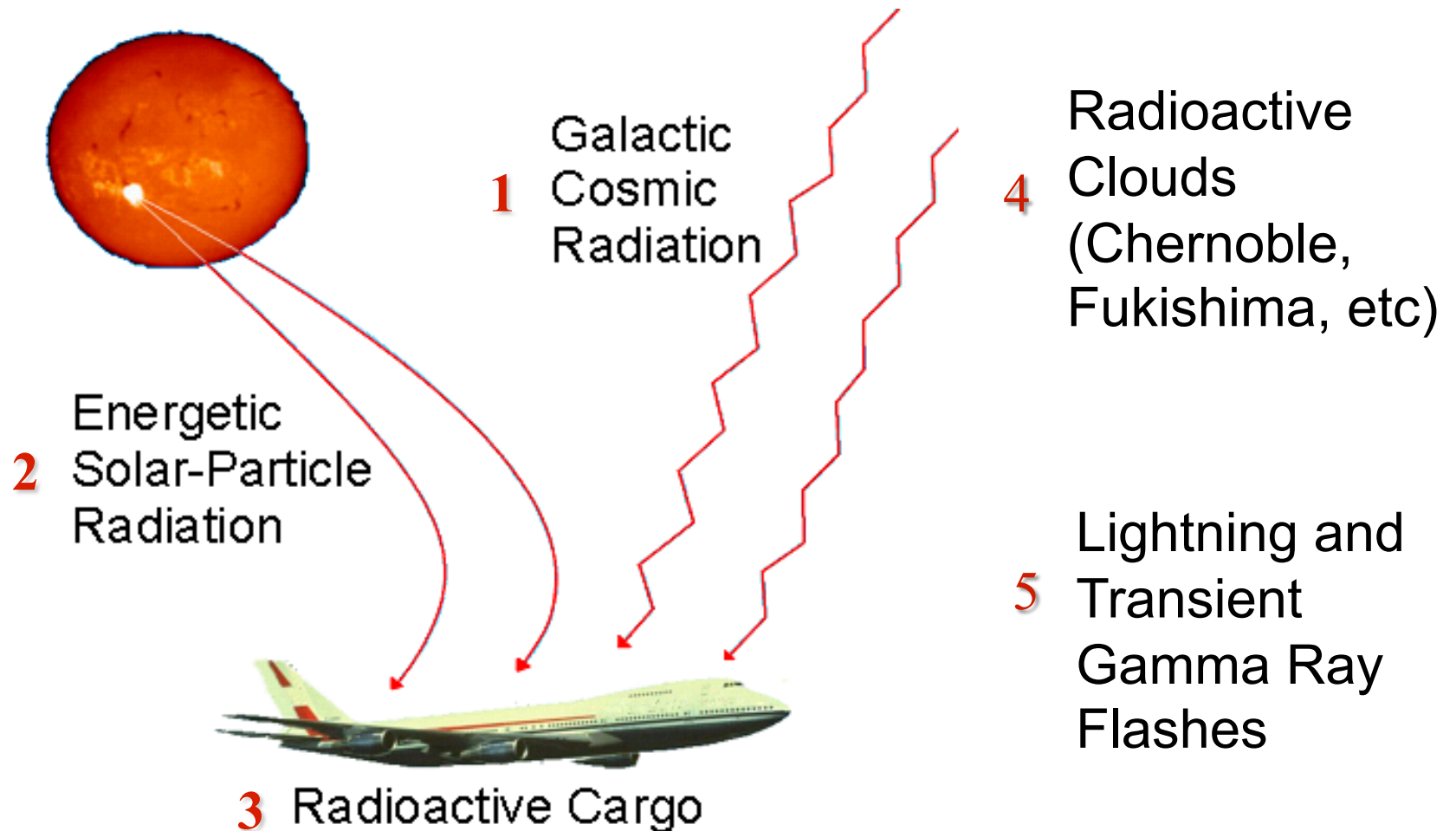
FAA Models for Ionizing Radiation Exposure

Galactic Cosmic Radiation:

CARI-6 (Accuracy is limited to 60,000 feet because of superposition approximation to HZE transport used by LUIN [O'Brien 1978])
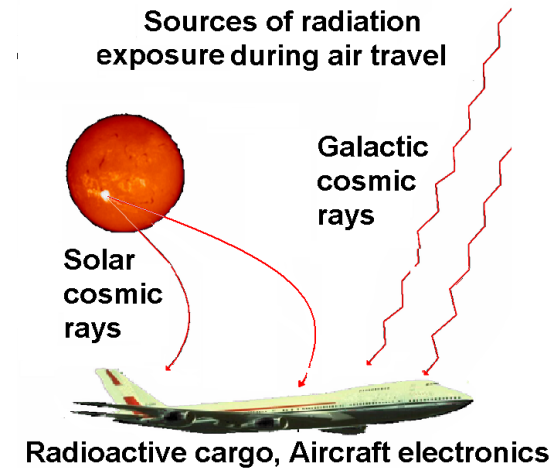
Solar Cosmic Radiation:

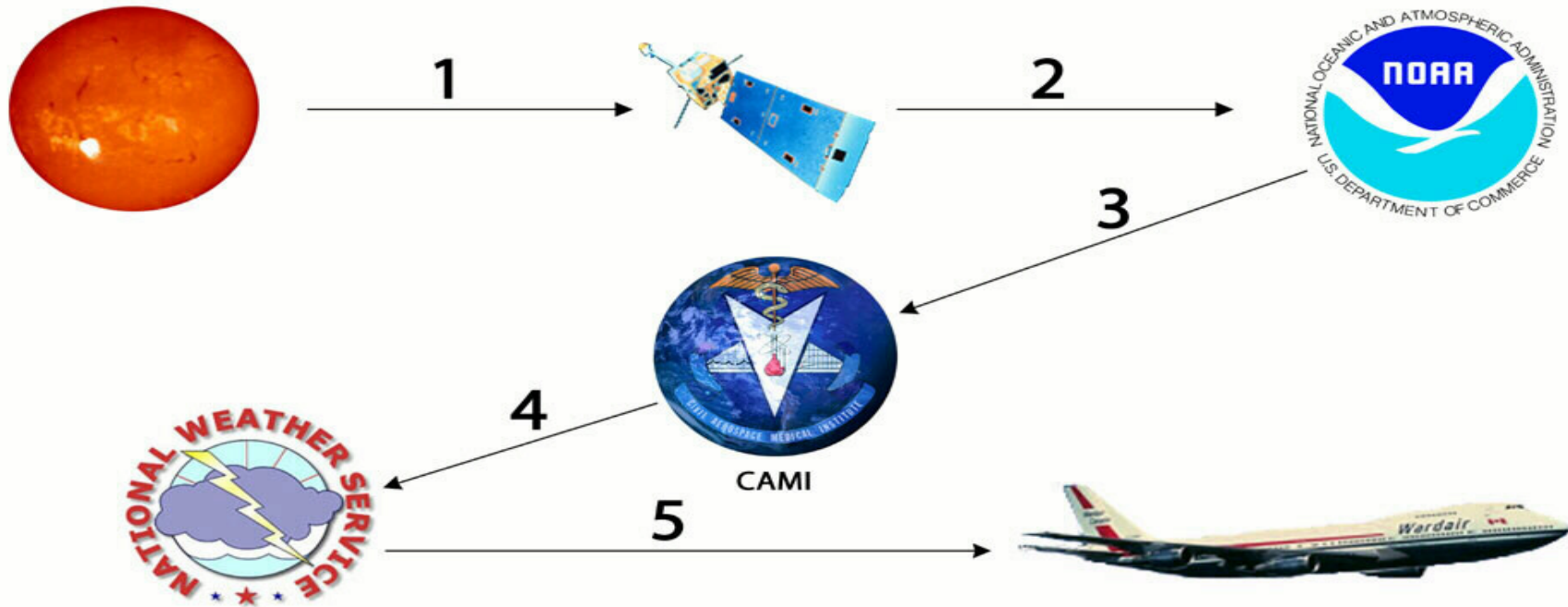Solar Radiation Alert System for real time
Ad hoc codes for after-the-fact

What is CARI?

(The old acronym for CAMI or…
One of Wally Friedberg's old girfriends)

- The first CARI program was released in the early 1990s. Based on LUIN transport code.
- A series of PC computer programs for calculating the dose of galactic cosmic radiation received on a flight.
- Used by pilots and airlines worldwide to monitor career radiation doses.
- Used by epidemiologists to estimate past exposures for radiation effects studies.

Sources of radiation exposure during air travel

Solar cosmic rays

Galactic cosmic rays

Radioactive cargo, Aircraft electronics

CARI-6W
18 November 2013

FNSL

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DVD DATA

SOLAR RADIATION ALERT SYSTEM

1. An eruption on the Sun raises radiation levels in Earth's vicinity.
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.

MCNPX
(Monte Carlo N-Particle eXtended)

Where does it come from?
Los Alamos National Laboratory

What is it?
A general-purpose radiation transport code based that uses Monte Carlo techniques.

Why use it for cosmic ray research?
It is capable of transporting all atomic species and dozens of subatomic particles and antiparticles at up to TeV energies.

What am I doing with MCNPX?

The 1976 US Standard Atmosphere has been used to create an input deck for MCNP6/MCNPX representing a set of 100 spherically concentric shells, each 1 km thick (Copeland et al, 2008). The density and composition of each shell is that at altitude of the middle of the shell, based on the reference data.

The properties of the atmospheric model are:

Maximum altitude above sea level   *100 km*
Area of its uppermost surface   *5.262×10^{18} cm^2*
Total atmospheric depth   *1035.08 g/cm^2*

Beneath the inner-most shell, the Earth is modeled as a sphere of liquid water of radius 6371 km and density 1 g/cm3.

Particles originate from the uppermost shell.

Empty space surrounds the uppermost atmospheric shell. Particles that leave the uppermost shell moving away from Earth escape.

Using MCNPX II

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}H$^+$), t(^{3}H$^+$), alpha, ^{3}He, 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.

The superposition approximation is eliminated. Doses can be calculated all the way to the top of the atmosphere.

After MCNPX . . .

One can estimate almost anything calculated or calculable from the data!

For CARI-7 and improved solar dose calculations shower data are reduced to dose rates at each tally altitude per unit fluence at the top of the atmosphere for each type and energy of primary particle.

Primary 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
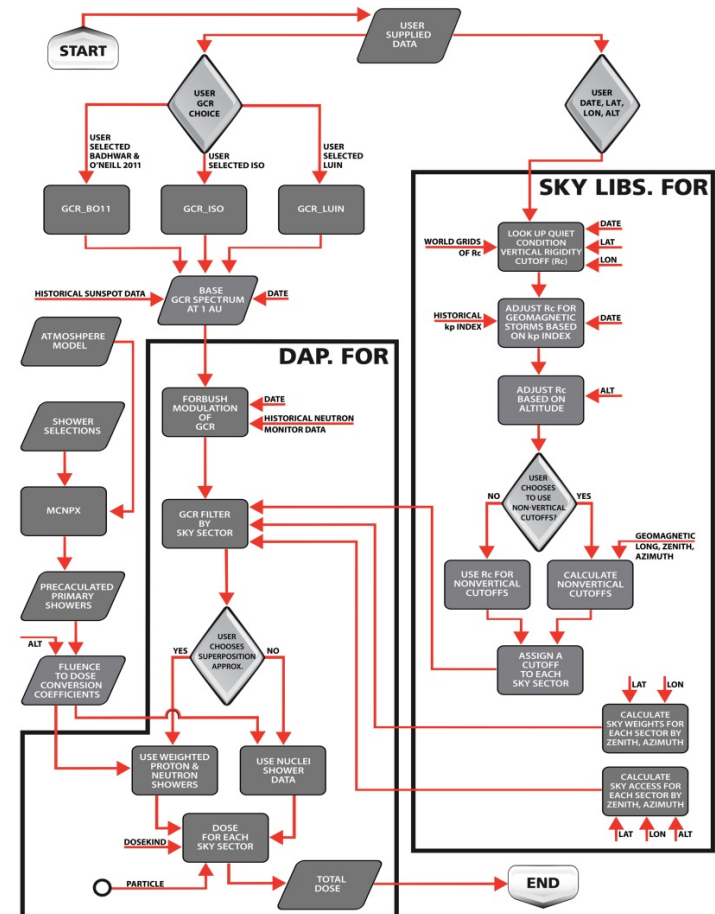
Some Weaknesses of the Approach

- Particles that escape cannot re-enter, even if they should.
- Shower data assume isotropic access to top of the atmosphere, which is an increasingly poor assumption at low geomagnetic latitudes.
- For spacecraft difficult to include effects of structure.

Future Work

- Revise to generate particle spectra at altitude, then convert to dose. This would allow adding filters for effects of aircraft/ spacecraft structure rather than approximating effects.
- Incorporate new shower data into solar calculations.
- Bring solar calculation up ad hoc standard with regards to inclusion of real-time neutron monitor data streams