United States Environmental Protection Agency

Radiation Protection Program

2024 CAP88-PC Training

RAMP User's Meeting

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Outline

- CAP88-PC Basics
- CAP88-PC Lessons for Best Uses
- STARGET Utility
- Set up for today’s exercise

CAP88-PC

CAP88-PC

- Clean Air Act Assessment Package 1988
- Created from mainframe algorithms for AIRDOS and DARTAB
- Uses a modified Gaussian Plume dispersion model to estimate doses to members of the public
- Primary purpose is for demonstrating compliance with the dose requirements found in 40 CFR Part 61, Subpart H - applicable to certain DOE facilities

What is a Gaussian Plume Model?

- Most common air pollution dispersion model
- Assumes constant emission and negligible diffusion in the direction of travel
- Mass is conserved in all directions
- Wind speed and direction are constant
- Emission rates are constant
- Radiation decay must be accounted for

Are the Results Realistic?

- CAP88-PC is a conservative compliance model
- Basic case assumptions “should” be designed to overestimate the doses for screening purposes
- If necessary, more realistic values can be entered where compliance is problematic
- Built-in assumptions that generally are conservative:
  - 24-hour release
  - Releases 365 days per year
  - Exposure 24 hours per day

Common Questions on CAP88-PC

Exposure Pathways

- CAP88-PC calculates the dose from airborne radionuclide releases to the Maximally Exposed Individual (MEI). In assessing this dose the following pathways are included:
- Ingestion – intake of radiation emanating from airborne releases
  - Including food (meat and leafy vegetables) and liquids (contaminated water and milk)
- Inhalation – intake of radiation through respiration
- Air immersion
- Ground surface irradiation
- Groundwater uptake not included

Emergency Releases

- CAP88-PC is not designed for use in modeling emergency responses or emergency planning. Other tools more commonly used in these situations are:
  - TurboFRMAC
  - HotSpot
  - RESRAD-RDD
  - HYSPLIT
- The Interagency Modeling and Atmospheric Assessment Center (IMAAC) led by the Federal Emergency Management Agency, can be called upon to answer questions about potential emergency releases of radioactivity.

Population Runs

Population runs are not required for regulatory compliance

- Air Quality Act of 1967 (CAA precursor) required compliance on a regional basis
- Population runs were developed to be compliant with this presumed requirement
- Finalized requirements do not have a population or ‘collective dose’ requirement

Agricultural Data

Agricultural data form the basis of the ingestion pathway in CAP88-PC.

- The ingestion pathway is not normally the majority pathway contributing to the dose assessment
- Food consumption rates for fractional food scenarios originate from data and lifestyles developed in the 1960s and 1970s
- Fractional food scenarios
  - Urban
  - Rural
  - Local
  - Regional
  - Imported
  - Entered by User

Short Term/Temporary Releases

CAP88-PC is designed for demonstrating compliance on an ANNUAL basis.

- Short term process emissions CAN be accommodated by the code
  - Some modifications may be necessary
- Be wary of the atmospheric conditions over the period of consideration
- For compliance purposes the user may need to ‘ratio’ the release to allow the code to properly represent the annual dose

Use of Surrogates

- When a facility is emitting a radionuclide that is not in the current suite of nuclides in CAP88-PC, the user may request a surrogate radionuclide be used in place of the subject radionuclide.
- User must submit the surrogate request in writing to the appropriate State or EPA regional contact
- User may suggest reasonable surrogate radionuclides
- The Agency/State will review and approve of the surrogate use
- Review will look at several factors for the surrogate including
  - Decay mode
  - Half-life similarity
  - Chemical similarity
  - Q Value Similarity
  - Availability

Limitations

- Turbulent wind conditions
- Mountainous or hilly terrain
- Non-uniform area sources
- Certain urban environments (building wake effects)
- Close proximity receptors

Tips and Takeaways

- CAP88-PC was developed for compliance with EPA’s rad-NESHAPs requirements
- It can and has been used to model radiation emissions for “other” purposes
- The user should be aware of the limitations and usefulness of the results from the model

CAP88-PC History (1 of 2)

- Initial Distribution composed of AIRDOS-EPA and DARTAB programs
  - FORTRAN 77 running
- AIRDOS and DARTAB Ported to PC in 1992 as CAP88-PC V1
  - FORTRAN 77 running under MS-DOS, character based input
  - Added risk calculations, pop doses, more data flexibility
  - Added DEFAULT program to verify use of EPA-approved data
- CAP88-PC V2 written for Windows published in 1999
  - Changed to Visual Basic user interface
  - Retained the original AIRDOS, DARTAB, DEFAULT programs
- CAP88-PC V3 written for Windows XP published in 2007
  - Changed to FGR-13 isotope set and dose/risk coefficients
  - Changed ground buildup model to address new isotopes
  - Updated to NCRP-123 environmental transfer factors

CAP88-PC History (2 of 2)

CAP88-PC V4 is the current version

- Age-Dependent DCFPAK 2.2 Values for Dose and Risk Factors
  - Build dose/risk factors in user interface code
  - 26 dose organs incl. Whole Body
  - Age Dependent Inhalation and Ingestion Rates
  - Values compiled by EPA from 2009 Exposure Factors Handbook
- Implementation of Numerical Solver for Chain Decay and Deposition
  - Handles chains up to 30 isotopes deep + branching
  - Chains defined in DCFPAK data
  - Implemented at each sector for air and ground surface
  - Replaces approximate methods used in V3
- New Compilers Allow Full Double Precision and Partial Vectorization reducing run time and eliminating underflow crashes

Version 4: Model-Based Limitations

- Up to 6 sources but all treated as being co-located with same plume rise method.
- Straight line Gaussian plume model limited for complex terrain.
- Coarse grid and sector-averaged calculations (can be helped by good modeler).
- Cannot use for short-term exposures unless weather data adapted (wind, rain, etc.).
- The code now supports shorter buildup periods and depositions.
- No groundwater pathway (may not be important for 1 year analysis).
- Surface water pathways not active in code.
- No ingrowth and decay in vegetation/meat/milk during season and holdup.
- Reg. Guide 1.109 based, could be easily updated now.

CAP88 Methodology

1. Calculate dose coefficients from DCFPAK Version 2.2 data (UI)
2. Calculate χ / Q values in each sector using long-term Gaussian plume
3. Calculate air concentrations in each sector including ingrowth
4. Calculate deposition rates in each sector using EPA policy values
5. Calculate ground concentrations in each sector for selected time
6. Calculate concentrations in vegetables, milk, and meat produced in each sector using NRC Regulatory Guide 1.109 method
7. Calculate concentrations in vegetables, milk, and meat ingested by a receptor in each sector (also using Reg Guide 1.109 method)
8. Calculate uptake by receptor for each pathway using EPA policy values
9. Calculate dose to a receptor in each sector as sum of uptake times dose coefficient for each pathway

Sector Air Concentration (1 of 2)

$$\chi(x,y,z) = \begin{cases} \dfrac{Q\left[exp\left(\dfrac{-[z-H(x)]^2}{2[\sigma_z(x)]^2}\right) + exp\left(\dfrac{-[z+H(x)]^2}{2[\sigma_z(x)]^2}\right)\right]}{2\pi\mu\sigma_y(x)\sigma_z(x)} exp\left(\dfrac{-y^2}{2\left[\sigma_y(x)\right]^2}\right) & \text{, if } x < 2x_L \\ \dfrac{Q}{2\sqrt{\pi}\mu L\sigma_y(x)} exp\left(\dfrac{-y^2}{2\left[\sigma_y(x)\right]^2}\right) & \text{, if } x \geq 2x_L \end{cases}$$

- x is the distance downwind [m]
- y is the crosswind distance [m]
- z is the distance above ground [m]
- Q is the release rate [Ci y^{-1}]
- μ is the wind speed [m s-1]
- $\sigma_y(x)$ is the horizontal dispersion coefficient [m]
- $\sigma_z(x)$ is the vertical dispersion coefficient [m]
- $H(x)$ is the effective stack height [m]
- x_L is the distance where $\sigma_z(x) = 0.47 \times L$

Sector Air Concentration (2 of 2)

- Averaging the concentration along the y direction:

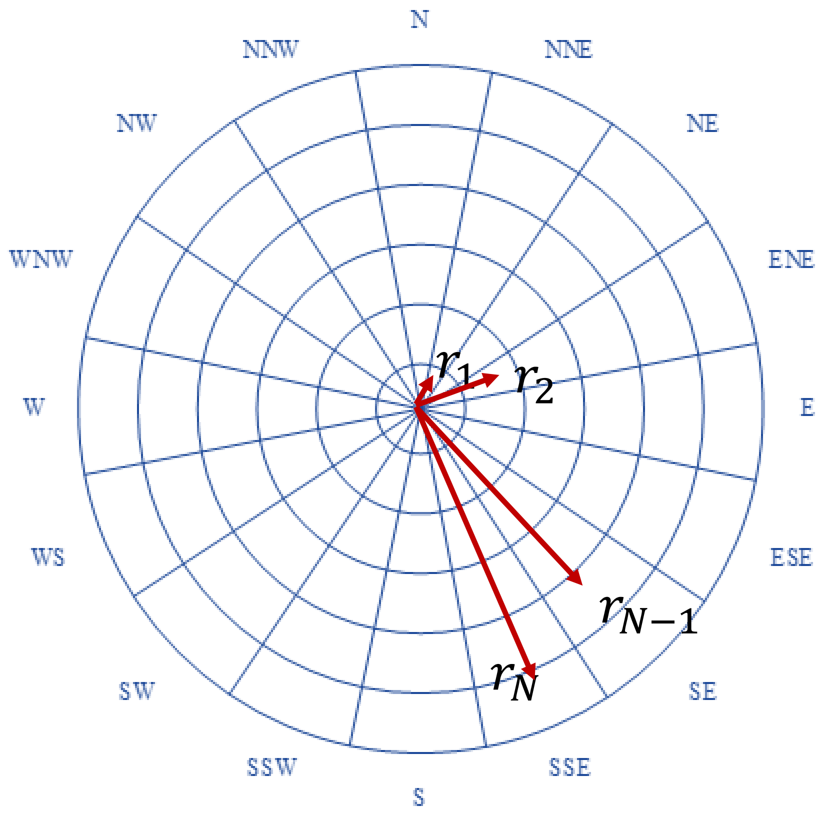
$$\chi_{\text{ave}}(x,z) = \begin{cases} \dfrac{Q\left[exp\left(\dfrac{-[z-H(x)]^2}{2[\sigma_z(x)]^2}\right) + exp\left(\dfrac{-[z+H(x)]^2}{2[\sigma_z(x)]^2}\right)\right]}{2\sqrt{2\pi}\mu\sigma_y(x)\sigma_z(x)} & \text{, if } x < 2x_L \\ \dfrac{Q}{2\sqrt{2}\mu L y_s} & \text{, if } x \geq 2x_L \end{cases}$$

- The ground level concentration is found by setting z=0:

$$\chi_{\text{ave}}(x,0) = \begin{cases} \dfrac{Q}{\sqrt{2\pi}\mu\sigma_z(x)y_s(x)}\left[exp\left(\dfrac{-[H(x)]^2}{2[\sigma_z(x)]^2}\right)\right] & \text{, if } x < 2x_L \\ \dfrac{Q}{2\sqrt{2}\mu L y_s(x)} & \text{, if } x \geq 2x_L \end{cases}$$

Assessment Area & Sectors

- CAP88 calculates the dose to receptors in sectors defined by radial distances and 16 compass directions.
- The radial distances are input by the user for individual runs or contained in the population file.
- The 16 compass directions are predefined in 22.5 degree arcs as shown.



Decay/Ingrowth Calculations

In-Flight

$$\frac{dn_i}{dt} = -\lambda_i^{e} n_i(t) + \sum_{j=1}^{i-1} \lambda_{j,i} n_j(t)$$

$$\lambda_i^{e} \equiv \lambda_i + \lambda_{l,i}$$
$$\lambda_{j,i} \equiv \gamma_{j,i} \lambda_j$$

- λ_i is the radioactive decay constant
- $\lambda_{l,i}$ is the physical removal constant
- $\gamma_{j,i}$ is the branching ratio from nuclide j to nuclide i

Ground Surface

$$\frac{dn_i}{dt} = d_i - \lambda_i^{e} n_i(t) + \sum_{j=1}^{i-1} \lambda_{j,i} n_j(t)$$

$$\lambda_i^{e} \equiv \lambda_i + \lambda_{l,i}$$
$$\lambda_{j,i} \equiv \gamma_{j,i} \lambda_j$$

- d_i is the total deposition rate
- λ_i is the radioactive decay constant
- $\lambda_{l,i}$ is the physical removal constant (2% per year)
- $\gamma_{j,i}$ is the branching ratio from nuclide j to nuclide i

Agricultural Fractions

κ_L^V

is the fraction of vegetables grown locally

κ_L^M

is the fraction of milk produced locally

κ_L^F

is the fraction of meat produced locally

κ_R^V

is the fraction of vegetables grown regionally in the assessment area

κ_R^M

is the fraction of milk produced regionally in the assessment area

κ_R^F

is the fraction of meat produced regionally in the assessment area

Agricultural Scenarios (1 of 2)

Urban	Vegetable	Milk	Meat
Fraction Home Produced	0.08	0.00	0.01
Fraction from Assessment Area	0.92	1.00	0.99
Fraction Imported	0.00	0.00	0.00

Rural	Vegetable	Milk	Meat
Fraction Home Produced	0.70	0.40	0.44
Fraction from Assessment Area	0.30	0.60	0.56
Fraction Imported	0.00	0.00	0.00

Local	Vegetable	Milk	Meat
Fraction Home Produced	1.00	1.00	1.00
Fraction from Assessment Area	0.00	0.00	0.00
Fraction Imported	0.00	0.00	0.00

Agricultural Scenarios (2 of 2)

Regional	Vegetable	Milk	Meat
Fraction Home Produced	0.00	0.00	0.00
Fraction from Assessment Area	1.00	1.00	1.00
Fraction Imported	0.00	0.00	0.00

Imported	Vegetable	Milk	Meat
Fraction Home Produced	0.00	0.00	0.00
Fraction from Assessment Area	0.00	0.00	0.00
Fraction Imported	1.00	1.00	1.00

Population vs. Individual Runs

- For population type runs (weighted by area):

$$w_{m,k} = \frac{1}{16}\frac{\left(r_m^2 - r_{m-1}^2\right)}{\left(r_N^2 - r_0^2\right)}$$

- For individual type runs (unweighted):

$$w_{m,k} = \frac{1}{16 \times N}$$

External Dose Rate from Direct Exposure to Activity in Air

$$\boldsymbol{D_j^X(r,\theta)} = \sum_{\boldsymbol{i}} \textbf{DFX}_{\boldsymbol{i,j}}\, \boldsymbol{\chi_i(r,\theta)}$$

- $\mathrm{DFX}_{i,j}$ is the air immersion dose factor for the jth organ for the ith radionuclide [mrem y^{-1} cm^3 μCi^{-1}]
- $\chi_i(r,\theta)$ is the air concentration of the ith radionuclide in sector θ at distance r [pCi cm^{-3}]

External Dose Rate from Ground Surface

$$\boldsymbol{D_j^G(r,\theta) = S_F \sum_i \text{DFG}_{i,j} \times C_i^G(r,\theta)}$$

- S_F is the attenuation factor accounting for shielding provided by residential structures (0.5)
- $\text{DFG}_{i,j}$ is the ground surface dose factor for the jth organ for the ith radionuclide [mrem y^{-1} cm^2 μCi^{-1}]
- $C_i^G(r,\theta)$ is the ground concentration of the ith radionuclide converted from the atom concentration in sector θ at distance r [pCi cm^{-2}]

LOGISTICS

Getting Started

WHAT DOES CAP88-PC REPORT

- Dose by sector for individuals and population
- Maximum individual dose and total population dose
- Air and ground radionuclide concentrations by sector
- Isotopic Chi/Q values by sector
- Radon exposure values for Radon-only cases
- Other information required by EPA as part of regulatory submittals

DOWNLOADING CAP88-PC

Download .NET Framework 4 from Microsoft (if not already installed)

http://www.microsoft.com/en-us/download/details.aspx?id=17851

Download CAP88-PC from the EPA's website

http://www.epa.gov/radiation

NOTE: First version of Wind file converter (STARGET) now available

INSTALLING VERSION 4.1.1

1. Install Microsoft .NET 4 Framework (Follow instructions provided by Microsoft) if not already part of system (should be in Windows 7-10).
2. Extract files from the compressed (ZIP) file if necessary
3. Right click the file “CAP88PCV41install.exe” and select “Run As Administrator” You may only have “Open” or “Run” available depending on permissions
4. Follow prompts; we recommend default installation locations
5. Location of user data files will be specified on first run using Migration Utility
6. Version 4.1.1 installs similar to Version 4.1 but adds ability to use remote file locations during Migration Utility operation on first run, and later using Tools>Options. Remote location references use the Universal Naming Convention format (*RemoteShareMachineName**folder*)

INSTALLATION NOTES

- Installation of CAP88-PC requires Administrator rights (Run As Administrator)
- Different major versions of CAP88-PC (e.g. V4.1 & V3) can be installed and run on the same machine simultaneously
- CAP88-PC can be installed to allow multiple users to run the code, but only one instance of the code can be run at a time, and only by one user at a time
- V4.0 will be removed by V4.1 installer, V4.1.1 will remove V4.1
- Installing V4.0 after V4.1 is not a supported configuration, similarly installing V4.1 after V4.1.1 is not supported
- Data files from earlier versions will not be deleted during installation
- CAP88-PC V4.1 is developed as a desktop application and is not supported for use as a cloud-based or server-side application at this time.

RUNNING CAP88-PC FOR THE FIRST TIME

1. After installing CAP88-PC V4.1, the “Migration Utility” must run to finish installing all the user data and create the folder structure:
   - Check “Copy v4 default …” if this is the first time the CAP88 is being run by that user.
   - Can select location of data folders and whether to migrate V3 files at this time
   - Click “Run” (This step creates the user folders)
2. If a reinstall, Select “Options” from the “Tool” menu:
   1. Click “Advanced”
   2. Click “Refresh FORTRAN”

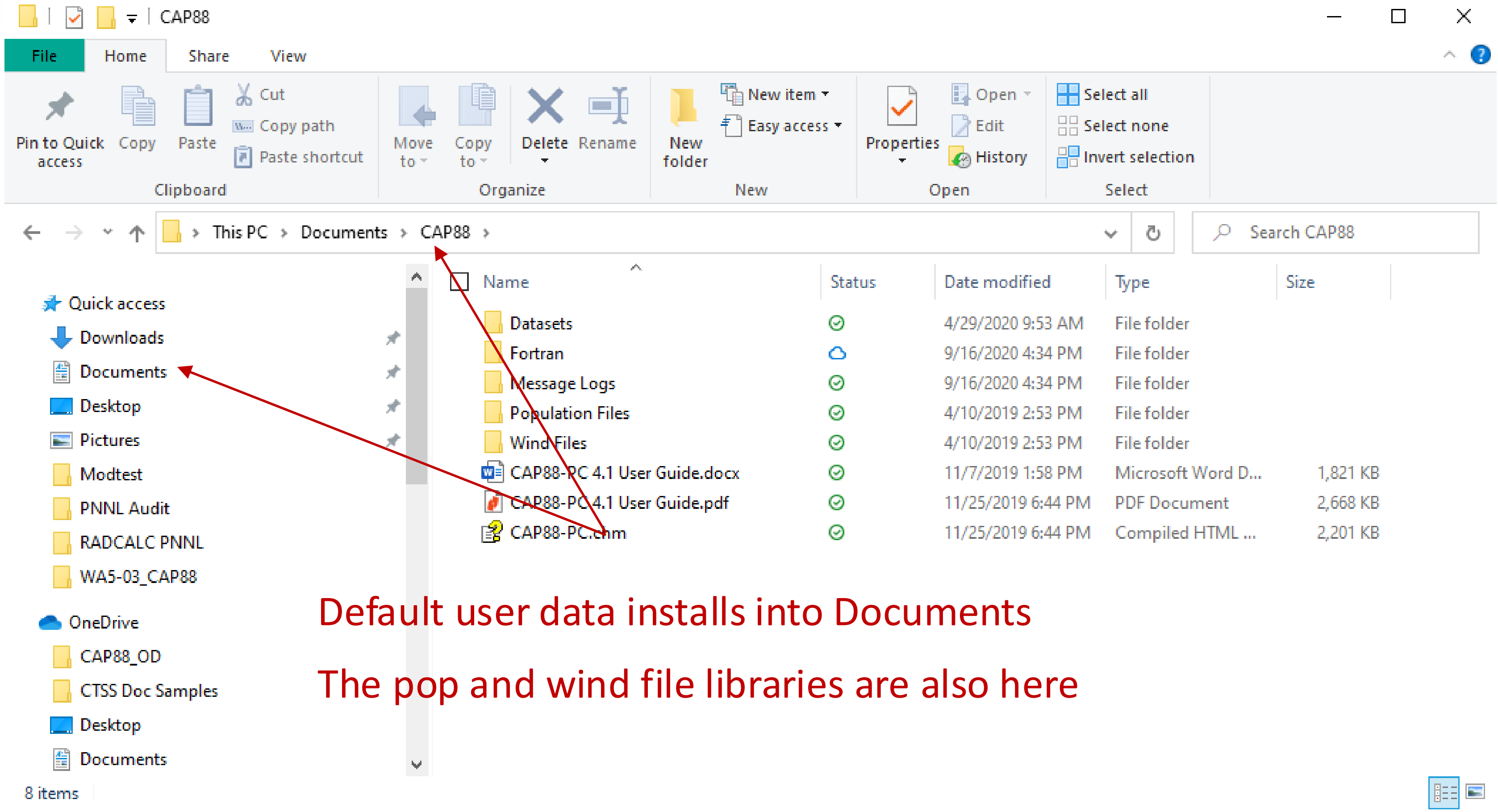
If a first time installation, the migration utility should automatically start upon first run

V4.1 detects V4.0 input files and performs in-place upgrade at runtime. Migrating data from V3 directly to V4.1 requires installation of Microsoft Access Data Engine. Instructions are included in the User Manual and Installation Notes.

CAP88 DATA FILE STRUCTURE

- User files, including wind and population files, are stored by default in a folder in the user's Documents Library/Folder
- The location where CAP88 stores files by default can be changed using the "Options" windows accessed through the "Tools" menu.
- Inputs are stored in a text file (with a .dat extension)
- Outputs are stored also stored in ascii text files (with .syn, .gen, .wea, .fac, .sum, .com, and .chi extensions)

CAP88 DOCUMENTS FOLDER

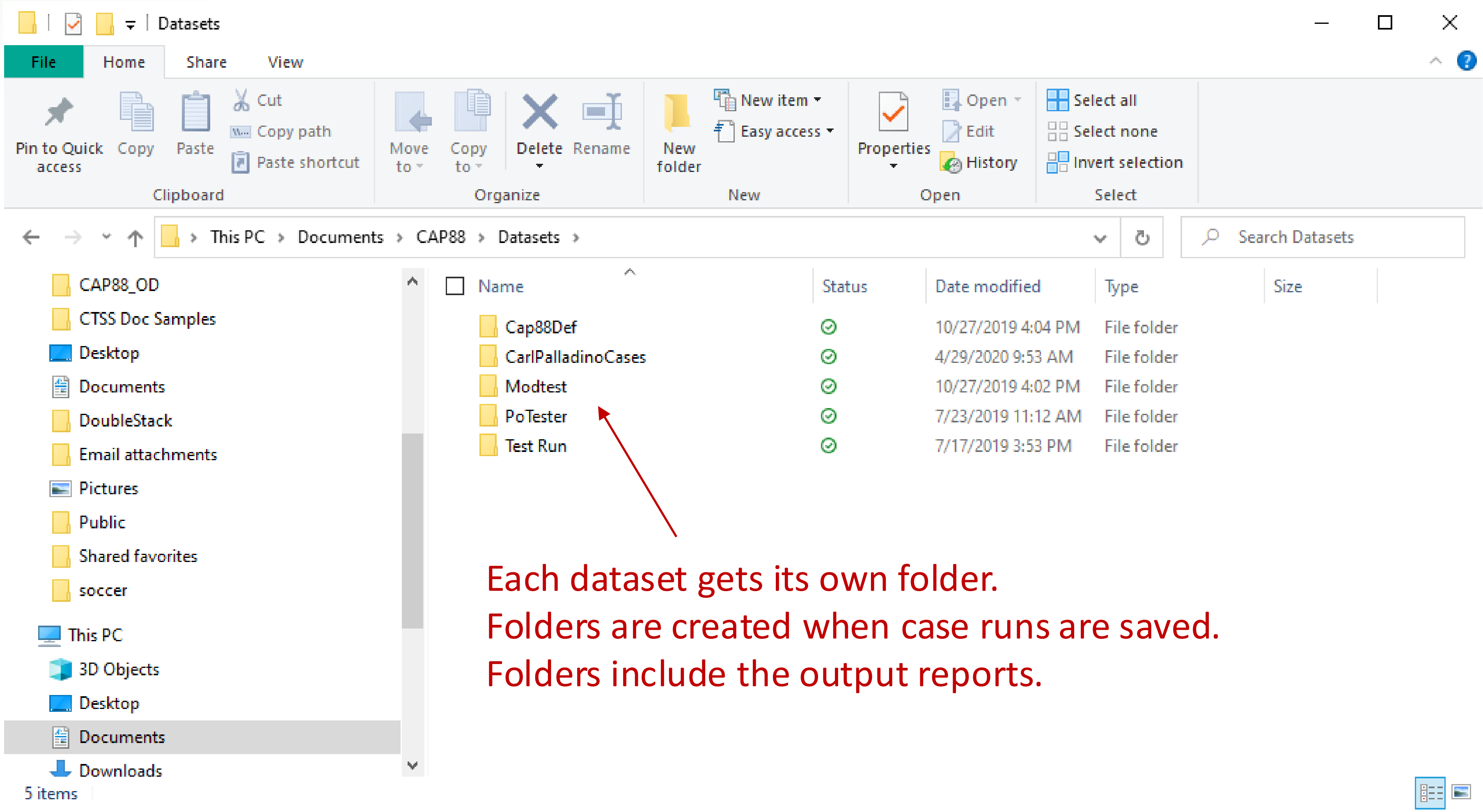


Default user data installs into Documents

The pop and wind file libraries are also here

NOTE: some systems may default the Documents folder to a cloud location

CAP88 DATASETS FOLDER



Each dataset gets its own folder.
Folders are created when case runs are saved.
Folders include the output reports.

V4 ARCHITECTURE

Separation of data from calcs

New data relationships

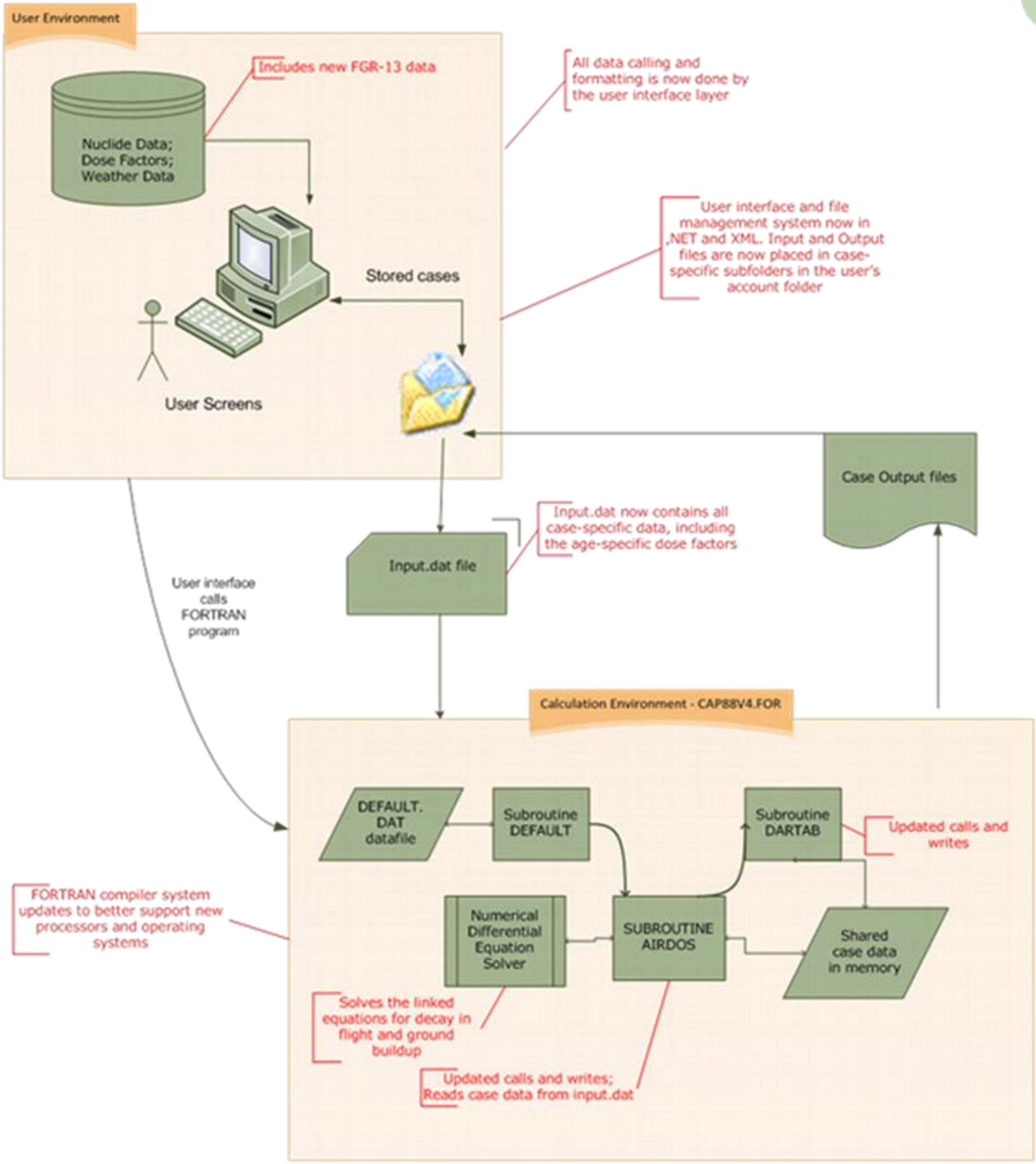
Single FORTRAN code

No temp files

Standard variable naming

Updated data and code standards

Enhanced Speed
Easier Maintenance
Better Case Configuration
Works with Windows 7+ Security



Reports

Seven Types of Reports

- Synopsis report (example.syn)
- General Data (example.gen)
- Weather Data (example.wea)
- Dose and Risk Summaries (example.sum)
- Dose and Risk Conversion Factors (example.fac)
- Concentration Tables (example.con)
- Chi/Q Tables (example.chi)

Are We Ready To Get Started?