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## HISTORY of MACCS

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Note that the name “MACCS2” was changed to “MACCS” in 2014. Versions of the code released prior to 2014, version 1.1.2 through 3.8.0, are called MACCS2 while versions 3.9.0 and newer are called MACCS.

The release history of MACCS is as follows:

MACCS2 1.12 was released in April 1997.

MACCS2 1.13, released to the NRC in September 2001, was created to correct inefficiencies found in MACCS2 1.12 and introduce an interface for WinMACCS, a Windows front end developed to support MACCS2 uncertainty analysis. The Fortran compiler was changed from LAHEY to DIGITAL Visual Fortran Professional 6.6A.

MACCS2 1.13.1, released to the user community in January 2004, is essentially the same as version 1.13. The only change in MACCS2 was to modify a default file name containing a list of files referenced in MACCS2. This default file in MACCS2 1.13 is MACCS3.tmp. The default file for MACCS2 1.13.1 and MACCS2 1.12 is MACCS2.tmp. The Fortran compiler used was changed to COMPAQ Visual Fortran Professional 6.6B.

MACCS2 2.4 was released to the user community in September 2008. Enhancements were implemented and bugs fixed.

MACCS2 2.4.0.5 was released to the NRC in November 2009. There were no enhancements. Bugs were fixed.

MACCS2 2.5.0.0 was released to the user community in May 2010. Bugs were fixed. There were no enhancements. The Fortran compiler used was changed to the Intel Visual Fortran Compiler version 11.1.

MACCS2 3.7.0.0 was released to the user community in February 2013. Bugs were fixed. There were no enhancements. The version number was synchronized to be consistent with WinMACCS.

MACCS2 3.8.0.0: was released to the NRC in February 2014. There were enhancements implemented and bugs fixed.

MACCS 3.9.0 was released to the user community in July 2014. Bugs were fixed. There were no enhancements.

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MACCS 3.10.0 was released to the user community in March 2015. There were enhancements implemented and bugs fixed.

MACCS 3.10.2 was released to the user community in July 2016. There were enhancements implemented and bugs fixed.

MACCS 3.11.0.1 was released to the user community in March 2018. There were enhancements implemented and bugs fixed.

MACCS 4.0.0.0 was released to the user community in June 2020. There were enhancements implemented and bugs fixed. Node locking was implemented.

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MODIFICATIONS MADE TO CREATE MACCS2 1.13<sup>2</sup> FROM MACCS2 1.12

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1) A validate-only option was added to allow input to be validated without running a calculation. For a validate-only execution, the content of the MACCS2.TMP did not change format. However, a 13-character string VALIDATE\_ONLY appears on line number seven as shown in the following example:

```
IN1A.INP
IN2A.INP
IN3A_N.INP
METSUR.INP
SURSIT.INP
LISTA_N.OUT
VALIDATE_ONLY
```

2) Support was added for status files to allow access to MACCS2- and Fortran-generated error messages created during the execution of MACCS2. The outcome of MACCS2 is communicated through files MaxStat.log and FortErr.log. MaxStat.log contains the string "OK" if MACCS2 terminates with no error. MaxStat.log contains the string "NO" followed by an informative message if MACCS2 detects an error. If MACCS2 crashes due to an undetected Fortran error, trace information is appended to FortErr.log.

3) MACCS2 was modified to optionally read the path and name of the file Maccs2.tmp as a program argument. The file name argument is preceded by the argument '-i'. For example, MACCS2 can be initiated from a command prompt window with the following command:

```
>MACCS2.exe -i "d:\My Maccs Files\maccs.tmp"
```

4) Error handling was improved.

5) A bug related to inconsistent results when using the source-term loop feature to analyze multiple releases was fixed. This fix resolves defect notifications M2V1-12A and M2V1-12B, both issued on 5/26/98.

6) Because restrictions of the new compiler, the scratch file on unit 22 was renamed temp99.

7) A new subroutine was added to verify that the sigma-y values (for all stability classes) at the maximum downwind distance (SPAEND (NUMRAD)) are within the limits of the algorithm used. If the plume covers an area greater than a semicircle (using 2.15 sigma-y to define the width of the plume, i.e., 10% of the centerline concentration) then the calculation does not proceed.

8) Debug information written to output file was removed.

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<sup>2</sup> Because versions 1.13 and 1.13.1 are essentially the same, the following discussion uses 1.13 generically to refer to either version.

9) Fixed bug that resulted in taking the log of zero when calculating TDECON, the time when the projected dose satisfies long term criterion,

11) MACCS2 incorrectly reported the food-chain doses from leafy vegetables and did not report the doses from grains. This bug was fixed.

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## MODIFICATIONS MADE TO CREATE MACCS2 2.4 FROM MACCS2 1.13

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New Models or Features Added. Model and input details are documented in the WinMACCS, a MACCS2 Interface for Calculating Health and Economic Consequences from Accidental Release of Radioactive Materials into the Atmosphere User's Guide and Reference Manual. The input instructions assume that the user is using WinMACCS to build MACCS2 input sets. Instructions to build MACCS2 input directly have not been included.

- 1) An optional dose threshold model was implemented. The linear, no-threshold, model was retained. The new threshold model can be run in one of two modes as follows:
  - a. Annual threshold used for latent cancer models. If the annual dose is less than the threshold for that year, all computed health consequences are zero for that year. Optionally, a lifetime dose threshold can be specified. If the lifetime threshold is exceeded, then all previous and future doses are included in the estimation of health effects, regardless of the annual threshold values.
  - b. Piecewise linear dose-response model allows a user-specified, dose-response curve to be used to calculate latent health effects.
- 2) An optional model for ingestion of KI was added. This model accounts for ingestion of KI by reducing doses to the thyroid from inhalation of radioiodine.
- 3) An optional plume buoyancy model was added. This improved model compares favorably with plume rise calculations using higher-fidelity models. The improved model is recommended for all future calculations.
- 4) An option was added for a long-range lateral plume dispersion model in which dispersion increases linearly with time, as recommended by Steve Hanna. The original dispersion model in MACCS2 was distance rather than time based.
- 5) Options were added to account for the effect of adverse weather on evacuation speed and also the effect of a nonhomogeneous road network on evacuation speed within each grid element.
- 6) An option to accommodate diurnal variations in mixing height was added. A new variable was added to support this, namely MAXHGT. Backward compatibility is supported by setting this value to DAY\_ONLY. In this case, the mixing height is a function of season only. If the value is DAY\_AND\_NIGHT, then the new diurnal variations are considered in the calculations. In this case, the mixing height is a function of season and time of day and a site location is required to determine daily variations in sunrise and sunset.
- 7) An option to eliminate doses from food and water ingestion was added.
- 8) Support was added for new dose conversion factor file based on Federal Guidance Report 13.
- 9) An option for a new plume meander model based on Regulatory Guide 1.145 was added. The ability to disable the plume meander model is also supported.
- 10) Support for angular resolutions greater than or equal to 16 to 64 in multiples of 16 was added.
- 11) Support for meteorological time resolutions of 15 and 30 minutes was implemented. Support for meteorological data recorded in 60-minute intervals was retained.

Changes to input values or limits are as follows:

- 1) Increased maximum number of particle-size deposition groups, VDEPOS, from 10 to 20.

- 2) Increased maximum value of CORINV from 1E+20 to 1E+25.
- 3) Changed range of values for INWGHT from 1 to 8760 to 0 to 35040.
- 4) The string TOTAL is no longer allowed as the first five characters of a user defined Health Effect name. An error message is printed if this occurs. TOTAL is a keyword for MACCS2 when used as the first 5 characters in a cancer effect name or an early injury name.
- 5) Extended NSMPLS for METCOD 2 and 5 as follows:
  - A. If METCOD = 2, limits for NSMPLS are 0 to 35040.
  - B. If METCOD = 5, limits for NSMPLS are 1 to 96.
- 6) A second method of running MACCS2 from the command line is supported. The command line parameters can be in any order. If a file is not needed (for example, say there is no CHRONC calculation), then no parameter is needed. If the `-i` option is used to specify a file containing filenames (if not specified, this is `Maccs2.tmp`), then the parameters specifying files (`-a`, `-e`, `-c`, `-m`, `-s` and `-o`) should not be used. If the parameters specifying files are used, then the `-i` options should not be used. The `-p` option is independent of these rules and can always be used. If parameters are used to specify files, then the `-o` option is required.

Added parameters are as follows:

- a ATMOS file
- e EARLY file
- c CHRONC file
- m meteorological file
- s site file
- o output file
- p prefix used for the status and Fortran error file names

Example: `maccs2 -e earlyfile.inp -o outputfile -a atmosfile -m meteorologicalfile -s sitefile`

This example has no CHRONC file, hence no parameter is given.

If `-p` isn't specified, the status files are named `MaxStat.log` and `FortErr.log`. If it is specified, then the names of the two status files are prefixed with this parameter. For example, `"maccs2.exe -p MyRun"` would result in status files `MyRunMaxStat.log` and `MyRunFortErr.log`.

- 7) Increased allowed number of evacuation cohorts (scenarios) from 3 to 20.
- 8) The following variables are no longer allowed to be change card variables per evacuation cohort. The values of these parameters are set in the EARLY input section are used in all evacuation cohorts.
  - a. DOSNRM
  - b. DOSHOT
  - c. ENDEMP
  - d. TIMHOT
  - e. TIMNRM
- 9) Added the optional variables LPROTIN, LBRRATE, and LGSHRAC to the CHRONC input cards. These values correspond to the EARLY variables as follows:
  - a. LPROTIN relates to EARLY variable PROTIN
  - b. LBRRATE relates to EARLY variable BRRATE
  - c. LGSHFAC relates to EARLY variable GSHFAC

Because there can be multiple evacuation scenarios in EARLY where the EARLY variables PROTIN, BRRATE, or GSHFAC can be different between scenarios, it may not be clear to the user which value is being used in CHRONC. The CHRONC variable cards LPROTIN, LBRRATE, and LGSHFAC are optionally used to specify the values in the CHRONC calculations for PROTIN, BRRATE, and GSHFAC. If LPROTIN, LBRRATE, or LGSHFAC do not appear in the CHRONC section of the input file, the values given to the corresponding EARLY variables for normal activity defined in the last evacuation cohort (scenario) are used. This is consistent with the behavior of MACCS2 prior to this change.

10) Added a new multiplier called ESPGRD to adjust the evacuation speed variable ESPEED, to take into account evacuation conditions. Limits on this new variable ESPGRD are from .01 to 10.0 with the default value being 1.0.

11) Increase maximum plume release segments, NUMREL, from 4 to 200.

12) RESCON and RESHAF are no longer allowed as change cards when defining multiple evacuation cohorts.

#### Improvements to Output:

1) Added a binary output file to store output to later be used by WinMACCS for viewing and analyzing data.

2) Added EARLY Type C output. For a given organ, the sum of contaminated land area is included in the output file when the dose in that area exceeds a user-defined threshold value. Dose values can be optionally reported for every grid element.

3) Added EARLY Type D output. For a given radionuclide, the sum of the contaminated land area within a selected radius is included in the output file when the contamination exceeds a user-defined threshold value. Ground and air concentrations can be optionally reported for the selected grid elements.

4) Made improvements to the format of the output file.

a. Removed extra page numbering and date headings

b. Removed unprintable characters showing up as box characters.

c. Corrected column headings to have the correct line feed.

d. Put column headings at the beginning of each new result type for EARLY and CHRONC.

e. Reformatted the date to be in the form Month Day, Year

f. Added an additional time stamp printed in the text output file and in the binary output file for quality assurance.

5) Removed the Joint Frequency table. This table was only needed for a special purpose SRS variant of MACCS2 version 1.12a.

6) Corrected results output when user-input IDEBUG is set to -1. No trial headings or numbers should be printed when IDEBUG = -1.

7) The label header CON, which represents CONSEQUENCE, has been replaced with CONSEQ and the result value NOT FOUND has been replaced with \*\*\*, with a footnote stating the following:

\*\*\* Indicates that the value is outside resolution of analysis. Optionally increase number of trials for better resolution.

8) Improved format of warning and error messages.

#### Bugs and Fixes:

1) The size of file names that MACCS2 can use was increased from 100 to 500 characters.

- 2) DCF files and Comida2 binary files can now have embedded periods in the path names.
- 3) Corrected error in Maximum Long-Term Action Distance output when IPLUME = 3.
- 4) Checks were added to prevent MACCS2 from reading and using an incorrect DCF file or COMIDA2 file. This had resulted in MACCS2 crashing. More informative messages are now printed if the wrong file is detected, if execution halts because of an incorrect file type, or if the file cannot be found. DCF and COMIDA2 files are no longer required to have a .inp and .bin extension, respectively. Any file extension can now be used.
- 5) Error messages have been improved and the error messages generated by MACCS2 are written to the status file, MaxStat.log.
- 6) Removed warning messages when plumes overlap. Prior to MACCS2 v1.12, the specification of plumes that overlapped in time was a fatal error.
- 7) Implemented more standard code to allow for more cross-platform compatibility between Windows and Linux.
- 8) Report array bound errors that are encountered.
- 9) Improved SIGMA Y validation has been implemented.
- 10) Implemented a test to see if at least one value for INWGHT is greater than 0. If not, an error message is printed to both the output file and the MaxStat.log file and MACCS2 stops.
- 11) Improved memory management in MACCS2 to use dynamic memory rather than storing intermediate/temporary values in files.
- 12) Corrected round off differences between values in the METEOROLOGICAL BIN SUMMARY table and the BIN WINROSE SUMMARY tables in the output file.
- 13) In the message notifying the user that a change card replacement record is replacing a previous record, the change card replacement record was numbered incorrectly. This has been fixed by correcting the record numbers that were reported in the output file when a record is replaced.
- 14) Extended the weather option to use the 120 user-defined values of mixing height if MAXHGT flag is set to DAY\_AND\_NIGHT. Previously, MACCS2 used the maximum of the 120 user supplied values or BNDMXH. If the MAXHGT flag is set to DAY\_ONLY the code performs as before by using the maximum of the 120 array values.
- 15) The travel time for the network evacuation was not calculated incorrectly in the case of radially inward travel. This has been corrected.
- 16) Plume release descriptions are required to be given in an ascending order of time delay. Previously, no check was performed to verify that the list of plume delay times was in ascending order. This resulted in an undiagnosed error. A test has been implemented to verify that the time delays are in ascending order. If not, MACCS2 stops and a descriptive error message is provided.

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MODIFICATIONS MADE TO CREATE MACCS2 2.4.0.5 FROM MACCS2 2.4

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Bugs and Fixes

- 1) The effects of the fine grid were not being considered when latent cancers were calculated. This resulted in over counting the number of latent cancers. During EARLY for the LNT model, populations in the fine grids that should be unaffected by the plume were calculated to incur health effects. For the case of Total Cancer Deaths, a calculation has been added to first determine the population in the fine grid elements that are available to be affected by the plume and that have not died from acute fatalities during the emergency phase. The Total Early Latent Cancer Deaths cannot exceed this number. Second, each individual cancer effect is restricted to only affect up to 100% of the available population per fine grid element. Third, the dose calculations passed on to CHRONC when running the Threshold Model also account for the effects of the fine grid calculations. These modifications eliminate double counting of fatalities. This problem existed in the original version of MACCS2.
- 2) An error was found in the previous version of MACCS2. While running CHRONC with the COMIDA2 food model, if the user set a latent organ to be false, then any health effect result using organs listed after the one set to false was incorrect because the wrong dose value was read from the COMIDA2 file. The doses in the COMIDA2 file are now read correctly. This problem existed in the original version of MACCS2.
- 3) Fixed a problem with the dispersion sigma-z lookup table being exceeded. When calculating sigma-z and the inverse of sigma-z, a problem could occur if first a stability class with a large sigma-z in the table was used but then the stability class changed to D, E, or F, where the maximum sigma-z value in the lookup table was not as large, and it had already been exceeded. A virtual source location could not be calculated for the new stability class because the maximum value in the table for that stability class was exceeded. When this occurs, the code version now uses the previous valid value of sigma-z until the stability class changes so that the maximum sigma-z value in the table is no longer exceeded. The code also issues a warning message in the output file.
- 4) Other improvements were made by increasing the number of reflection terms calculated and tightening the test for uniform mixing to ensure accurate calculation of Chi/Q values. These improvements are only important when the Day and Night Mixing Height model is activated.

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MODIFICATIONS MADE TO CREATE MACCS2 2.5.0.0 FROM MACCS2 2.4.0.5

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Note: MACCS2 Version 2.5.0.0 was compiled with the Compaq Fortran compiler version 6.6B.

Bugs and Fixes

1) Introduced changes required to allow this version of MACCS2 code to be compiled on the newer Intel Visual Fortran Compiler version 11.1. These changes have no effect on the results of MACCS2 calculations.

2) Fixed a problem with the Plume Meander Model US NRC Regulatory Guide 1.145 (MNDMOD=NEW). When the downwind distance where the effect of the meander begins to diminish (value of MNDIST) is set to be equal to a spatial grid endpoint the EXPFAC factor was not being set to 1.0 as it should have been. The code logic was corrected so that EXPFAC is now set to 1.0.

3) Tests have been added to more fully verify the data in a meteorological data file.

- a) A test has been added to check for the largest wind direction used in the weather file. If the maximum wind direction used is less than NUMCOR then a warning message is printed to the output file. Example of warning message is

WARNING: The largest wind direction found in the weather file was 16, but NUMCOR is set to 32

- b) Now checking for missing data in the weather data arrays after the meteorological (weather) file has been read in. Previously, MACCS2 would only verify that the weather data values were in the correct range, but MACCS2 did not verify whether a period of weather was missing. Now MACCS2 checks the weather data arrays for missing data. If MACCS2 detects missing data, an error message is printed and MACCS2 stops. An example error message is below:

ERROR: Data was not found in the weather file:  
The weather data for Period 14 of Day 2 is not valid. Check the weather data file for missing data.

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MODIFICATIONS MADE TO CREATE MACCS2 3.7.0.0 FROM MACCS2 2.5.0.0

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1. Synchronized version number to be consistent with WinMACCS version number of 3.7.0.
2. Intel Fortran compiler:  
The Intel Fortran compiler is now used to create the MACCS2 executable.  
Intel(R) Visual Fortran Compiler Integration Package ID: w\_cprof\_p\_11.1.051
3. Dispersion sigma-y lookup table:  
Code was added to test for the case where the sigma-y table values are exceeded. If they are exceeded, MACCS2 prints an error message and then stops.
4. Dispersion sigma-z lookup table:  
Warning messages that the sigma-z lookup table has been exceeded are no longer printed to the file that is displayed by WinMACCS after MACCS2 finishes running. A warning message declaring that the dispersion table for sigma-z has been exceeded is now only printed once per weather trial to the MACCS2 text output file.
5. SUMPOP population distribution option:  
In the case where only one cohort was defined when using the SUMPOP option, MACCS2 would report an error and stop. This problem has now been fixed.  
In the case where 10 or more cohorts are defined when using the SUMPOP option, MACCS2 would report an error and stop. This problem has now been fixed.  
When using the SUMPOP option the results for each cohort were not being weighted correctly in the calculation of some of the overall results. This was also true for the results being calculated for the CHRONC cohort while using the threshold model. Both the overall results and the CHRONC results have now been corrected.
6. KI model:  
The KI model was showing different results from previous versions of MACCS2 but there had been no change in the code for the KI model to account for this difference. A change in the code not related directly with the KI model that was causing this problem has now been fixed and the KI model values are correct.
7. Land Area Exceeding Dose Results and Land Area Exceeding Concentration:  
The Land Area Exceeding Dose Results and Land Area Exceeding Concentration output showed zero results regardless of the threshold value (ELEVDOSE or ELEVCONC) specified if CHRONC was not run and not site file was used. This problem has now been fixed so that the Land Area Exceeding Dose results and Land Area Exceeding Concentration results are reported correctly. To fix this problem, the variable FRACLD has been moved into the EARLY input file and it now appears in the EARLY variable

section in the WinMACCS interface. Additionally, the behavior with respect to old MACCS2 input card decks has been modified in the following ways:

1. If running an old MACCS2 input deck, not running CHRONC, not using a site data file, and requesting Land Area Exceeding Dose and/or Land Area Exceeding Concentration results, an error is reported.
2. If running an old MACCS2 input deck, running CHRONC, not using a site data file, and requesting Land Area Exceeding Dose and/or Land Area Exceeding Concentration result, the calculation proceeds normally. In this case, FRACLD is read from the CHRONC input file and used.

In addition, the Land Area Exceeding Concentration results are now only printed in the overall results and not with the individual cohort results since the results are identical for each cohort. Also, the Land Area Exceeding Dose result does not make sense to sum by weighted cohort values for the overall results, so it is no longer being displayed with the overall results but only with the individual cohort results. The dose values per grid are displayed as before in both the overall results and by individual cohorts.

8. DCF file path name:  
MACCS2 was not allowing the DCF file path name to be longer than 100 characters. This has now been corrected so that the path name can be up to 500 characters long.
9. PLMDEN variable:  
The lower limit for the variable PLMDEN was changed from .2 to .02. This is consistent with WinMACCS and the MACCS2 User Manual.
10. Plume Meander Model:  
The Plume Meander Model shown in Regulatory Guide 1.145 was originally implemented incorrectly. Values should have been interpolated using a logarithmic scale rather than a linear scale.

This equation was used in the previous versions:

$$f(u) = 1 - (u-u_1)/(u_2-u_1) * (m-1)/m \quad \text{when } u_1 < u < u_2$$

This is the correct equation using a logarithmic scale that MACCS now uses:

$$f(u) = (1/m) * \exp( \log(m) - ((\log(u)-\log(u_1))/(\log(u_2)-\log(u_1))) * \log(m) ) \\ \text{when } u_1 < u < u_2$$

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MODIFICATIONS MADE TO CREATE MACCS2 3.8.0.0 FROM MACCS2 3.7.0.0

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1. Population Movement Result Type:  
A new EARLY user result request type called the Population Movement Result has been introduced. This result type tells the user the fraction of population that has evacuated to chosen distance versus time since accident initiation. See the file named WinMACCS Improvements for a complete description of how to use this result type.
2. Keyhole Model:  
A new variation of Radial and Network evacuation has been introduced, called the "Keyhole Model". For a complete description on how to use this new model, see the file named WinMACCS Improvements.
3. Units Conversion Option:  
A Units Conversion option has been introduced with this version of MACCS2. It allows the user to specify different units and displays the output in the units chosen by the user. See the file named WinMACCS Improvements for a complete description of how to use this option.
4. PEOPLE population distribution option:  
In previous versions of MACCS2, the individual EARLY cohort results reported in the output were calculated based on the entire population. Calculations are now done based on the actual population of the cohort for each grid element. This now matches the way the calculations are done with the SUMPOP population distribution option, and the results in the output reflect this change. Therefore, the following message appearing before each EARLY cohort has been changed from:  
  
"RESULTS FOR A SINGLE EMERGENCY RESPONSE COHORT WITHOUT ANY WEIGHTING FRACTIONS BEING APPLIED"  
  
Now reads as follows:  
  
"RESULTS FOR A SINGLE EMERGENCY RESPONSE COHORT"
5. Speed Multiplier Option:  
MACCS2 did not prevent a user from running the code when using different speed multipliers per grid with IPLUME equal to 1 or 2, both of which include rotation. Rotation should be used if the speed multipliers are not the same for every grid element. Therefore, a check has been added to prevent MACCS2 from running if the Speed multipliers option is being used with IPLUME equal to 1 or 2.
6. SUMPOP Population Option:

The survivor's population used in CHRONC was calculated incorrectly when the SUMPOP option and the Threshold model were used. It has now been corrected. In previous versions a population fraction was being included in the calculations which was initialized to 0.0 and never changed. This had the effect of never subtracting any deaths from the survivors array created in EARLY, so CHRONC always used the entire population for its calculations. This error has been present since the EARLY Survivors array was first implemented in version 2.2.0.0 but is now fixed.

7. Network Evacuation option:

The calculation of Economic results when using the Network evacuation option has been corrected. In the previous version of MACCS2, this error was causing the code to calculate the EMERGENCY PHASE COST as if every grid element was affected by the plume. This caused a higher EMERGENCY PHASE COST in the network evacuation case.

Corrected the Network evacuation option calculations for the amount of time needed to travel through a grid element when using the TRAVELPOINT flag set to "BOUNDRY". It was discovered that the distances traveled when using the Network evacuation option with the TRAVELPOINT Flag set to "BOUNDRY" were not calculated correctly. Previously, MACCS2 was only calculating straight through paths which did not take into account the case where the grid element was not being entered in the same direction that it was being exited. This creates an L shaped path since the people are required to pass through the center point of the grid.

8. MACCS2 Inputs variables:

a. Land Area Exceeding Concentration Result:

MACCS2 now allows a user to choose up to 40 output requests of this type.

b. Land Area Exceeding Dose Result:

MACCS2 now allows a user to choose up to 40 output requests of this type.

c. Chemical Groups:

MACCS2 now allows a user to have up to 150 Chemical Groups.

d. Plume Segments

Increased maximum plume segments (MAXNP) allowed from 200 to 500.

9. Reading Input files:

The maximum length of an input card that MACCS2 can read has been increased to 2300 characters long.

An error could occur if the input file contained no change cards. This problem was fixed.

10. Output File:

Extra blank spaces at the end of a card are now no longer printed to the output file. Also extra blank spaces at the end of filenames are also no longer printed.

11. Economic Cost Results:

An error has been corrected that caused incorrect Economic Cost results to be written to the binary file when the Boolean Print Flag was set to "FALSE" for an Economic Cost result.

12. Decay Chain Calculations:

MACCS2 was not reporting missing nuclides when doing decay chains when more than 110 nuclides were used. This potential error has been in the code for some time. It was corrected.

13. Release Inventories:

An error would occur if a radionuclide has a very large half-life combined with a large inventory. This would cause MACCS2 to assign a value of Infinity to the release inventory value for that radionuclide, which would then corrupt any calculations using this value. A test has been implemented for this case and if the test determines that the release inventory value generated is infinity. If this condition occurs, MACCS2 stops with an error message advising the user what steps can be taken to correct this problem.

14. Land Area Exceeding Dose Results:

Errors were discovered in the way that "Land Area Exceeding Dose Results" were printed in the CHRONC cohort in both the text output file and the binary output file, which is used to generate reports in WinMACCS. These errors have now been corrected so that the "Land Area Exceeding Dose Results" for the CHRONC cohort have the correct values and labels.

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MODIFICATIONS MADE TO CREATE MACCS 3.9.0.0 FROM MACCS2 3.8.0.0

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1. Removed references to "MACCS2" to just say "MACCS":  
Changed word string "MACCS2" to "MACCS" everywhere it is used in output that a user would see except if referring to a model such as the "Original MACCS2 1.12 Briggs Model" etc. Also the comments in the code have not been changed.
2. The Population Movement results for the overall cohort were not calculated correctly:  
The calculation of the individual cohort fraction for the Population Movement (Type E) results has been corrected. Before the correction, the entire population of a cohort over the entire grid was used to calculate the fraction. Now the calculation is correctly using just the population inside the radius distance, given by the user, from which the population movement percent is being calculated. This fraction is used when summing the individual cohort values into one overall cohort value.

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MODIFICATIONS MADE TO CREATE MACCS 3.10.0.0 FROM MACCS 3.9.0.0

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**Enhancements:**

1. A new optional user input variable TIMRTN:  
TIMRTN is the time at which evacuees return after it has been determined that none of the plume segments traveled over their grid element. This variable is in the EARLY input file.
2. Multiple source option:  
MACCS reads an input file where multiple sources have been defined and combined into one file. MACCS then computes the effects of each source and combines the results into one output.
3. Maximum emergency-phase time and release durations:  
The following variables of the emergency phase have new upper limits as listed below:

OALARM	up to 30 days
PDELAY	up to 30 days
ENDEMP	up to 40 days

4. User defined variable dose-projection periods:  
Previously, the ENDEMP variable was used to define the dose projection period for the emergency phase and the DUR\_INTPHAS + ENDEMP time was used as the dose projection period for the intermediate phase.

Two new users input variables have been added to the code to allow the user to define the dose projection periods, as follows:

DPPEMP	Dose-projection period for the emergency phase with the range (0.0 to 1.0E10 seconds)
DPP_INTERPHAS	Dose projection period for the intermediate phase with the range (0.0 to 1.0E10 seconds).

If the optional variable DPPEMP is not set by the user and does not appear in the input file Early.inp, then the old value of ENDEMP is used as the default. If the optional variable DPP\_INTPHAS is not set by the user and does not appear in the input file CHRONC.inp, then the old value of DUR\_INTPHAS + ENDEMP is used as the default.

Also the current user input variable, TMPACT, which defines the dose-projection period for the long-term phase, has had its range changed to be 0 to 1.0E10 seconds.

5. A new CHRONC output request type reports the number of people evacuated and relocated.

For each result requested the user provides an inner and outer radius from which to calculate the number of people being impacted.

There are 10 different categories reported:

1. Number of people evacuated during emergency phase not affected by the plume
2. Number of people evacuated during emergency phase affected by the plume
3. Number of people relocated by normal relocation
4. Number of people relocated by hotspot relocation
5. Number of people relocated during intermediate phase
6. Number of people relocated from level-1 decontamination during long-term phase
7. Number of people relocated from level-2 decontamination during long-term phase
8. Number of people relocated from level-3 decontamination during long-term phase
9. Number of people relocated from highest level of decontamination + additional interdiction time
10. Number of people permanently relocated from condemnation

Variable Name: NXUM14

Variable Type: Integer, Scalar

Allowed Range:  $0 \leq \text{value} \leq 10$

Purpose: Specifies the number of this type of result blocks to be printed.

Variable Name: I1DS14

Variable Type: Integer, Scalar

Allowed Range:  $1 \leq \text{value} \leq \text{NUMRAD}$

Purpose: Defines the inner spatial interval of the region of interest for this result block. The user must supply NXUM14 values in column 1 of the data block.

Variable Name: I2DS14

Variable Type: Integer, Scalar

Allowed Range:  $I1DS14 \leq \text{value} \leq \text{NUMRAD}$

Purpose: Defines the outer spatial interval of the region of interest for this result block. The user must supply NXUM14 values in column 2 of the data block.

Example of use:

TYP14NUMBER 2

**	I1DS14	I2DS14	CCDF flag
TYP14OUT001	1	10	none
TYP14OUT001	4	10	none

6. SVN Revision number was added to the MACCS code. This revision number has also been appended to the version number that appears in the text output file and the binary output file.
7. The default file name that is used when no input parameters are given on the commandline when executing MACCS was changed from "maccs2.tmp" to be "maccs.tmp". This change is invisible to users using WinMACCS to run MACCS.
8. Data from the weather file used for a weather trial were increased to be 1200 hours (50 days) rather than 120 hours (5 days). Boundary weather is used when these data are exhausted. Boundary weather can still be used in the outer portion of the grid, and this is controlled by the LIMSPA variable.
9. The limit of output lines that MACCS could output, 3394 per cohort, was increased. Dynamic memory is now used, so the limit is only dependent on the memory of the computer.

### **Bug Fixes:**

1. ATMOS Output: Day and Hour, used to select a start were reversed in the output and have now been corrected. The Day and Hour were printed only for the case of METCOD = 5 and IDEBUG = 3 or greater. The values were correct for all other cases when this output was shown.

Also, both the stratified random sampling case and the user specified Day and Hour case have been changed to account for the new weather file time intervals in the same way that bin sampling was modified when the the new weather intervals were first introduced.

2. The problem of calculating the Centerline Dose and Centerline Risk results for the overall cohort was fixed for the case when the population of the given area is zero but the Centerline Dose or Centerline Risk are not zero.

The problem was that a value of zero was shown in the overall cohort when a positive value was shown in the individual cohorts. Previously, the fraction used to multiply the individual cohort Centerline Dose or Risk value, to create its contribution to the overall cohort, was calculated from the population based on the area given by the user, and then divided by the total population of all cohorts in this given area, this would lead to a the Centerline Dose or Risk value being multiplied by zero if no population existed in the area. The code has been changed so that if the total population in a given area is zero, the fraction calculated uses the area that includes all grid elements to calculate the cohort fraction value.

3. Relocation times calculated in CHRONC were being done incorrectly by not taking into account the difference between cohorts. Previously, the evacuation/relocation behavior calculated during the emergency phase that was

- used in CHRONC for cost and other calculations was based on the last emergency-phase cohort. This was incorrect for the case where two cohorts occupy the same grid but one evacuates and the other does not. MACCS has been corrected so that evacuation/relocation behavior is now saved for each grid element per cohort during the EARLY calculations. The relocation doses, risks, health effects, and costs calculated in CHRONC were affected by this change.
4. Several problems with the Population Movement output (Type E) were corrected.
    - a. MACCS was not printing Population Movement output values to the output file as designed. The values being printed were not taking into account multiple Population Movement requests. MACCS now distinguishes between each result request so that all time steps intended are printed. The following time steps are printed for each Population Movement request.
      - i. Time step at 0.0 seconds.
      - ii. Time step with 0 percent that precedes the first time step with a positive value.
      - iii. Each Time step with a change in value.
    - b. Population Movement results were not correct when using multiple weather trials with the Keyhole Model. The Peak Trial value was never greater than 1. The array DLTEVA was being updated by the keyhole model calculations but was not being reinitialized to the original DLTEVA values for the next weather trial. This caused the incorrect DLTEVA values to be used for all weather trials after trial #1. This has been corrected.
    - c. The time period that movement was recorded was not long enough for some cases. Previously, the end of the time period that movement was recorded was 1 day. In the case of circular evacuation, the maximum time that evacuation is considered is now  $OALARM + \text{the maximum (DLTSHL (i) + DLTEVA (i)) + one day}$ . The keyhole model could trigger evacuation at any time during plume releases, therefore, the maximum time that evacuation is considered, when the keyhole model is used, has been increased from 87600 seconds to be the greatest value of  $( PDELAY(i) + PLUDUR(i) ) + 1 \text{ day}$ .
    - d. Reduced the number of type E values printed to the binary file to be the same as the values printed in the text output file. This eliminates unneeded values from being printed to the binary file that slows down the processing of the binary file by WinMACCS.
  5. The Keyhole Model was sometimes exhibiting incorrect results and was implemented inefficiently by continuing to look at weather periods when no longer needed.
    - a. Incorrect results were caused by an incorrect index also used for the variable OALARM. This has now been corrected. This error had unpredictable effects on the output.
    - b. The number of weather periods used in the implementation of the keyhole model was corrected. Previously, all weather periods were used. This resulted in changes in wind directions being used that were not needed and usually caused the number of wind directions being evacuated to exceed the trigger point of 180 degrees at which point all compass directions (360 degrees) would evacuate. The keyhole model only needs to use weather periods up to the maximum time found from summing

PDELAY plus PLUDUR for each plume segment (i.e.,  $\max(\text{PDELAY}(i) + \text{PLUDUR}(i))$ ). After this point, any weather changes have no effect on evacuation and therefore should not be considered for the keyhole.

6. There were several errors in the output of the ATMOS plume segment result requests (Type 0).
  - a. First, because of a formatting error, MACCS was only able to support plume segments labels with a single digit in the plume number. For example, if there were 15 plume segments and the user requested output for plume 10, 11, 12, 13, 14, or 15, then the plume would be labeled "Plume \*" rather than "Plume 10" etc. MACCS can now display labels of plume segments with up to 3 digits (i.e. "Plume 999").
  - b. Second, plume segment values did not match plume segment labels in the output file. The results were printed in the wrong order if the user did not ask for them in the order they were defined in WinMACCS. This is true for the order in which the plumes appear as well as the radii requested. For example, plume 1 radius 1, plume 2 radius 2, plume 1 radius 3, etc. So, the user had to have the correct plume order as well as inner most radius of a plume for an outer radius request for the output to appear correctly. This has been corrected so that no matter what order the plume segments are requested, they are printed correctly with the corresponding correct values.
7. The doses using the A-Skin organ were not being calculated correctly in the case of Normal or Hot-Spot relocation. This has now been corrected.
8. The text output file was incorrectly reporting how many Impacted Area/Population Results (Type 12) values were printed for the CHRONC cohort. This has been corrected.
9. Peak dose values (Type A) using acute organs were being reported for the CHRONC cohort. These doses should only be calculated and reported for the EARLY Phase. The peak dose values (type A) from acute organs have now been removed from the calculations and output for the CHRONC cohort.

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MODIFICATIONS MADE TO CREATE MACCS 3.10.1.2 FROM MACCS 3.10.0.0

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**Enhancements:**

1. New optional latitude and longitude input lines are read from the ATMOS input file.

New names are as follows:

M1LATITUD01 and M1LONGITU01. Each will contain one real number, either latitude or longitude in degrees as a decimal format.

Example:

M1LATITUD01        39.85     (range -90.0 to 90.0)  
M1LONGITU01       -79.8443 (range -180.0 to -180.0)

MACCS will look for the old input for latitude and longitude if the new input lines are not found.

**Bug Fixes:**

1. To be consistent, the cohort names in the binary output file have been changed to be the same as those printed to the text output file.

The following labeling is now used in both files:

**Overall cohort label = "Overall"**

**1<sup>st</sup> Cohort label = "Cohort 1"**

...

**Nth Cohort label = "Cohort N"**

**CHRONC cohort label = "CHRONC"**

N = total number of evacuation cohorts

2. An error was found that could miscalculate the time people are in a grid element when the evacuation type is set to Network and the TRAVELPOINT option is set to BOUNDARY. When evacuation was completed during the beginning subphase, the time was calculated correctly. When evacuation lasted into the middle and late subphases, then the value was calculated incorrectly. This error has been present since MACCS 3.8. This error has now been corrected.
3. An error in an ATMOS decay rate equation was found and corrected. This error was a syntax error dealing with a parenthesis being in the wrong place. This error affected a localized calculation of radioactive decay but seems to have a negligible impact on results.
4. An extra output value, called RETCOD, that is printed to the text output file when the EARLY debug option variable IPRINT is set to a value greater than 8 was not being printed correctly when NUMCOR was greater than 16. This has been corrected.

5. An error in the calculations for centerline doses was introduced in version 3.10.0.0 when implementing the user defined dose projection period enhancement in EARLY. The error was that the centerline doses were calculated for the dose projection period, but then not re-initialize to 0.0 when the actual centerline doses were calculated. This caused the dose projection period centerline doses to be summed with the values of the actual centerline doses, which causes reported centerline dose results to be incorrect. This has now been corrected.
6. When the EARLY debug option flag, RISCAT, is set to true the RELATIVE CONTRIBUTION TO THE MEAN FROM EACH WEATHER CATEGORY BIN (%) is printed for each result. The following problems have been corrected:
  1. The columns headings are now printed correctly.
  2. The output was set to print 32 bins, but the actual number of bins could be different than 32. Therefore, the actual number of weather bins is now printed up to the max of 40. Also, the page of Xs is no longer printed between source term outputs in the text output file.
7. Previously, each weather trial DAY and HOUR that was printed in the output text file was the day and hour that the first plume segment was released. When the user tries to replicate an individual weather trial, the input values of day and hour need to correspond to those of the MAXRIS plume, not the first plume. This difference in the meaning of DAY and HOUR inputs and outputs made it difficult for the user to replicate a single weather trial from a weather sampling calculation.

Example: the code picks a time, such as DAY = 210 and HOUR = 5, and this time represents the weather hour of the MAXRIS plume segment. If MAXRIS is not the first plume segment, then the output time was adjusted to be the hour of the first plume segment. Suppose the first plume segment is 24 hours ahead of the MAXRIS plume segment, then the time is adjusted to DAY = 209 and HOUR = 5. This adjusted time was the value printed to the output file. But if a user wished to reproduce this weather trial, they did not get the same result when they used ISTRDY = 209 and ISTRHR = 5 that is shown in the output file.

To prevent this confusion and to help the user to know what DAY and HOUR to use to reproduce a single weather trial using the ISTRDY and ISTRHR input variables with METCOD = 1 (fixed start time), the DAY and HOUR that refers to the start time of the MAXRIS plume is now printed to the output file for each weather trail. Thus, the definition of start time in the output is now consistent with start time in the input.

8. A bug was fixed in the keyhole model. The DLTEVA times were not being re-initialized correctly to the input values at the start of each new weather trial.

9. A bug was fixed in the keyhole model. Originally, the direction of the MAXRIS plume segment was considered when defining the initial size of the keyhole. Plume segments prior to the MAXRIS plume segment were ignored for the purpose of defining the size of the keyhole. The logic was modified to define the size of the keyhole based on plume segments starting with the first one.

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MODIFICATIONS MADE TO CREATE MACCS 3.11.0.1 FROM MACCS 3.10.1.2

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**Enhancements:**

1. The OALARM variable has been moved from being defined as an ATMOS variable to now being defined in as an EARLY input variable and is read from the EARLY input file. It is a change CARD variable. This allows OALARM to be different for each cohort.
2. Dosimetry Enhancement: Organs used in calculations can now be any organ appearing in a DCF file. All organs listed in the DCF file are now shown in WinMACCS and the user can decide to use all or any subset. This list is given to MACCS as the list of organs to be used in the calculations.  
The COMIDA2 binary input files have been changed to include doses for all organs from the corresponding DCF file.
3. The temporary MACCS Threshold model file named chrndfFactors.bin is now created in the same directory as the ATMOS input file. This corresponds to the "Input" directory in a WinMACCS project directory.
4. LNT ADJ POP DOSE and the USED ADJ POP DOSE were removed from the calculations and text output file for the Health Effects results. This output was generated only in the threshold model cases and was determined to be not useful and potentially confusing.
5. In MACCS version 3.10.0.0, Type C and Type D results were removed from some cohorts in the binary output. This change has been reversed and now all Type C and Type D results have been restored to all cohorts in the binary output file. The motivation for this change was to facilitate regression testing.
6. The maximum allowed values of CDNFRM and CDFRM were increased from 1.E5 to be 1.E6.
7. When a memory allocation error occurs a more informative message is now printed with suggestions on how to eliminate the error.
8. The value of NUMEFA (number of early fatality effects) was increased to 10. The upper limit of NUMACA (number of latent cancer effects) was increased to 40.
9. The error message that was displayed if the DOSNRM value exceeded the value of DOSHOT has been improved.
10. MACCS is now compiled as a 64-bit executable, preserving the same compiler options as the 32-bit executable where possible. This enhancement has eliminated running out of memory errors that have occurred in the past.
11. One variable was created to represent seconds in a year ( $1\text{year} = 365.25 * 24 * 3600 \text{ seconds} = 31557600.0 \text{ seconds}$ ) throughout MACCS. This change has a very minor effect on results.
12. MACCS now reads an optional CARD, "RDNUCSCA," from the atmos input file for each radionuclide. This scalar is a real number with a inclusive range of 0.0 to 1.0 (no units). This vector of values serves the same purpose as CORSCA, but at the radionuclide level rather than then entire inventory.
13. The maximum values allowed for the variables DUR\_INTERPHAS and TIMDEC(x) ( x represents the level of decontamination) have been increased to

- 30 years (in seconds). This comes with the restriction that **ENDEMP + DUR\_INTERPHAS + TIMDEC(x)** cannot be greater than 32 years.
14. The report flag value "CCDF" or "NONE" for the Type C and Type D results input CARD has now been implemented. MACCS now prints the CCDFs for Type C and/or Type D results to the text output file if the report flag is set equal to "CCDF."

### **Bug Fixes:**

1. A potential error when using the Multiple Source option has been corrected. It was possible that an incorrect first plume release time (PDELAY) might have been used under certain circumstances. Normally PDELAY(1) corresponds to the first plume segment to be released. With the addition of the Multiple Source term option, this is no longer guaranteed to be true. The MACCS code now correctly identifies and uses the earliest plume segment.
2. MACCS now supports MelMACCS header strings up to 500 characters. MelMACCS header strings are optional and only appear in the text output file when they are available to WinMACCS and are passed to MACCS through the ATMOS.inp file.
3. Warning messages for the Reg. Guide 1.145 plume meander model were fixed. Previous warning messages only appeared when the plume segment durations were greater than 10 hours. The Reg. Guide 1.145 plume meander model is designed for plume segment durations of 1 hour and should produce a warning when they are greater than 2 hours. MACCS now tests for release durations of greater than 2 hours when using Regulatory Guide 1.145 plume meander model.
4. An error was introduced in MACCS version 3.10.1.2 when printing the DAY and TIME PERIOD values for weather starting with the MAXRIS plume segment was implemented. The text output file was reporting DAY = 0 and TIME PERIOD = 0 for constant weather and for user-defined weather cases. The correct DAY and TIME PERIOD for the weather trial are now being printed to the text output file.
5. Several corrections were made to the optional output (aka Debug output). That is provided when the Output Control variables IDEBUG, IPRINT, or KSWTCH are given values greater than zero.
  - a. Organ indexing was corrected.
  - b. NUMCOR columns were corrected for the case when NUMCOR has is greater than 16.
  - c. Incorrect values of RETCOD printed in the CHRONC section were corrected.
6. An error that caused MACCS to crash when using the User Supplied weather case has been corrected. The error had been introduced in MACCS version 3.10.0.0 with the enhancement that increased the number of weather points available from 120 to 1200.
7. Several corrections and changes have been made to the Impacted Population Results (CHRONC Type 14 results).
  - a. Results are now calculated when the MACCS Food Model (Old Food model) is used.
  - b. EARLY survivor populations are now used to calculate the impacted population result values for CHRONC related impacts:

- i. Populations relocated from decontamination.
    - ii. Populations relocated from decontamination plus interdiction.
  - c. Previously, printed values for decontamination levels 1, 2, and 3 even when the decontamination level was not defined. Now only calculating and printing impacted population results for decontamination levels that are defined in the project.
- 8. An error was found that MACCS did not support having both the /NUMCOR and the /PERIOD values in the same Meteorological file. MACCS has now been corrected so that both keywords are read and dealt with correctly when they both appear in a Meteorological file. The Keywords /NUMCOR and/or /PERIOD must appear on a line after the first 2 header lines and before the weather data starts. /NUMCOR can appear before or after the /PERIOD keyword. Both the /PERIOD and /NUMCOR variables are optional.
- 9. The change CARD "EZEVAKEY001" was found to not be read when the Keyhole Model is not being used. Even though the the Keyhole model is not used, this CARD (by default) still appears in the EARLY input file with the value of "NONE". But because MACCS did not need it and it was not read a warning message was printed to the text output file stating the the following:

```
***** WARNING -- THE FOLLOWING RECORDS WERE NEVER ACCESSED  
*****
```

```
EZEVAKEY001 NONE
```

To avoid confusion by the user wondering why the CARD was not read, it is now read in all cases so the warning message does not appear. The correction does not affect any calculations. Therefore, the only change in the output that is that the warning message is no longer printed.

- 10. When running the Piecewise Linear Dose Model, MACCS crashed because of a memory allocation error. This error has now been corrected.
- 11. A duplicate "AFTER ADJUSTMENT" print statement in the text output file that appears when the weather start time has to be adjusted has been removed.
- 12. There was a discrepancy for the range of allowed values for Reg Guide 1.145 plume meander parameters: WINSP1, WINSP2, and MNDIST in the MACCS code and the range stated for these parameters in the WinMACCS interface and the MACCS user's guide. The WinMACCS user interface and the MACCS user's guide both state that the ranges are as follows:  
WINSP1 = 0 to 20 meters per second  
WINSP2 = 0 to 20 meters per second  
MNDIST = 0 to 10,000 meters  
However, the actual bounds enforced by the MACCS code were:  
WINSP1 = 2 to 20 meters per second  
WINSP2 = 6 to 20 meters per second  
MNDIST = 800 to 10,000 meters  
The MACCS ranges have been corrected to match the WinMACCS interface and the MACCS user's guide.
- 13. Because of the additions of new time stamp, Economic Multiplier, and Latitude and Longitude to the Site file header description line that is printed to the text output file, MACCS now allows site header strings up to 500 characters in length.

14. The use of the new emergency phase Dose Projection Period value (DPPEMP) has been corrected. Dose calculation times were being limited to (ENDEMP + first plume arrival time) for all cases. Now the time value DPPEMP is used correctly.
15. With the the increase of the maximum value of ENDEMP from 7 days to 40 days, the corresponding Groundshine integration periods needed to be increased from a maximum of 7 days to a maximum of 40 days. This has now been done.
16. MACCS now enforces that the values of PERIOD and NUMCOR be in columns 9 and 10 if these optional values appear in the weather file. This now matches MACCS User Manual's description of the weather file format for this data. An error message is given and MACCS stops if this is not true.
17. A memory error was found and fixed that caused MACCS to crash. The error occurred in the rare case where the user asked for Type D results but did not ask for any Population Movement results are any CHRONC results (i.e. Type D request is the last output request).
18. MACCS no longer allows an acute organ to be defined as the CHRONC long-term critical organ. If an acute organ has been defined then an error message is printed and MACCS stops.
19. The early-survivors population per grid, which is used for the population in the CHRONC phase calculations, was being calculated incorrectly by subtracting both the Early Fatalities and the Latent Fatalities from the early phase. Only early fatalities are now subtracted.
20. An error in the Threshold model was fixed for the dose calculation if time that people return after the intermediate phase or after intermediate phase + decontamination is greater than 1 year. Any time over one year was not being accounted for.
21. The calculation of the intermediate-phase economic cost for population interdiction was corrected. Previously, MACCS set the intermediate-phase population interdiction cost to zero for a grid element when there was not going to be a long-term phase cost for that grid element. The MACCS code has now been corrected to calculate and report the intermediate-phase population interdiction cost in the case where the long-term phase cost is zero. The interdicted population calculations of the Action Distances Results (Type 11) and the interdicted population and interdicted area calculations of the Impacted Area/Population Results (Type 12) will also be effected by the correction of the economic interdiction cost. This is because, in the case of interdicted values, a grid is included in the calculation of the Action Distances and Impacted Area/Population values based on whether the grid's economic interdiction cost is greater than zero.

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MODIFICATIONS MADE TO CREATE MACCS 4.0.0.0 FROM MACCS 3.11.0.1

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**Special Notes:**

1. There is a new set of COMIDA2 data input files for FGR13. These files include 50 years of food dose data. The user should use these new files, which contain the new COMIDA2 version number, 2.0.0.2, as part of the name. For example, comida2\_2.0.0.2\_FGR13DCF.bin should be used with the DCF file named FGR13DCF.inp and comida2\_2.0.0.2\_FGR13GyEquiv\_RevA.bin should be used with the DCF file named FGR13GyEquiv\_RevA.inp.

**Enhancements:**

1. HYSPLIT ATD model option: The HYSPLIT model is a complete system for computing complex dispersion and deposition simulations. HYSPLIT can use most gridded weather data sets. The HYSPLIT ATD option can be used in place of the Gaussian plume segment model in ATMOS. Computation and data requirements are much larger with the HYSPLIT option.
2. Alternative Economic model: RDEIM (Regional Disruption Economic Impact Model) estimates the offsite cost impact in terms of GDP losses from business disruption using current state-of-practice I-O economics. It includes indirect effects on the national economy outside the directly affected region and induced economic effects to the regional and national economies resulting from lost income to workers.
3. Animation file option: There is now an option to create text files that describe plume movement and ground and air concentrations. These files can be used as input to an animation software program, AniMACCS, that can display them as animations.
4. Node locking: The MACCS 4.0.0.0 executable is node locked with a key file that allows it to run on a single node. Node locking requires a user to have a product key file that is unique to each computer. MACCS will not run on a computer without a product key file.
5. Values method for calculating quantiles CCDFs: This is a new method of calculating the quantile values for a set of weather trials called the Values method. The old method in the code, referred to here as the Binning method, uses a predetermined set of bins (usually 46 bins) to categorize the magnitude of the consequence result. After each weather trial the results are assigned to one of the 46 bins. After each weather trial ends, the results are discarded, and the next weather trial is calculated. After all the weather trials are finished, the data stored in the bins are used to estimate the quantile values from the predetermined bin ranges. This method has been found in some cases to be inaccurate and often not to be able to resolve some of the quantile values even when an adequate number of weather trials were performed. With the new Values method, each consequence result for each weather trial is saved. After running all the weather trials, the saved values are ordered to calculate the actual quantile values and CCDFs in a rigorous fashion.
6. Economic model cost output sub results: **POP-DEPENDENT INTERDICTION COST** is replaced by the following 3 new cost categories:

- a. **POPULATION-DEPENDENT LOSS OF USE**
- b. **POPULATION-DEPENDENT DEPRECIATION LOSS**
- c. **LONG-TERM RELOCATION COST**

**FARM-DEPENDENT INTERDICTION COST** is replaced by the following 2 new cost categories:

- a. **FARM-DEPENDENT LOSS OF USE**
- b. **FARM-DEPENDENT DEPRECIATION LOSS**

The old **POP-DEPENDENT INTERDICTION COST** is the sum of the new subcategories, **POP-DEPENDENT LOSS OF USE**, **POP-DEPENDENT DEPRECIATION LOSS**, and **LONG-TERM RELOCATION COST**.

The old **FARM-DEPENDENT INTERDICTION COST** is equal to the sum of the two new subcategories, **FARM-DEPENDENT LOSS OF USE** and **FARM-DEPENDENT DEPRECIATION LOSS**.

7. All economic loss values that use a property value in the equation to calculate the results for the type 10 economic cost, including the “LOSS OF USE” and “DEPRECIATION LOSS” costs, are now calculated using the site file economic property values when the site file is available (rather than using the generic user defined property value given in the WinMACCS interface).
8. If the project uses a DCF file, MACCS now prints the values that it has stored in memory for each organ from the DCF file to the text output file.
9. MACCS is now compiled with Intel FORTRAN version 15.0 compiler.
10. Options to print all fine grid dose values for a given organ to a binary file and to print dose values for a user-specified set of grid elements to a text file has been added. These options can be activated by using keywords and parameters in a file named maccs2.ini that must be located in the directory with the MACCS executable.
11. The maximum number of output result requests that can be made for each individual request type (i.e., NUM0, NUM1, NUM2 ...) has been increased to a maximum of 999. This ability is only limited by the available memory of the machine being used.
12. The option to have MACCS use files rather than dynamic memory to store temporary values is no longer available.

**Bug Fixes:**

1. MACCS now uses double precision variables to test if ENDEMP + DUR\_INTPHAS + TIMDEC is greater than 32 years. The variables that are used to sum the values when testing whether the sum is greater than 32 years have been changed to be double precision variables to help limit problems using large

- numbers. This has fixed inconsistencies except in cases where the difference is about 35 seconds or less.
2. Previously the Type 11 Interdiction Distances and Type 12 Impacted Interdiction Area/Population results were determined based on whether the interdiction cost for a given grid element was greater than zero. This was incorrect in rare cases when the cost to interdict a grid area was zero. To eliminate this problem, the internal MACCS long-term action code (LTACTN) is now used to determine whether to count a grid element for Type 11 Action Distances and Type 12 Impacted Area/Population Interdiction results. This is consistent with how MACCS currently uses the LTACTN codes to calculate the Type 11 Action Distances and Type 12 Impacted Area/Population results for Decontamination and Condemnation values.
  3. Previously, the mixing height for the next plume segment started with the mixing height of the last hour of the previous plume segment when using the DAY\_AND\_NIGHT option for MAXHGT. This was incorrectly implemented. The mixing height is now reset to the actual mixing height at the starting hour of each new plume segment.
  4. MACCS now limits the value LASTACUM to the range of 9 to 50 years, inclusive. Values less than 9 years are not allowed. MACCS prints an error message if the value of LASTACUM is outside this range and the program stops. LASTACUM is the last year for which the COMIDA2 model gives accumulated and projected food doses.
  5. In some cases, some values of a CCDF were not printed to the binary file. This was caused by a test that was incorrectly coded to check for two CCDF values being equal. This caused all values after finding two equal values to be printed as undefined even if they were defined. This has been corrected so that all defined values of the CCDF are printed.
  6. When attempting to compile MACCS with the Intel Fortran compiler version 15, it was discovered that several minor changes to the code were required. In two cases, errors were found.
    - a. First correction fixes calculations of the population movement timing for Population Movement result type E.
    - b. Second correction fixes calculations made for the plume rise values. This can affect the calculations of the values of ground air concentrations and ground-level dilution values of Type 0 results. It can also affect calculated doses and other results affected by doses.
  7. The time for radioactive decay in subsequent source terms when using Time Offsets with the Multi-Source option in MACCS was corrected. The multi-source option in MACCS was not accounting for radionuclide decay as intended. There should not have been any decay between MACCS time 0 and the time offset value for the associated source term. However, the time offset input was only being used to offset the PDELAY release time and radionuclide decay was calculated between MACCS time 0 and the time offset for subsequent sources. This has been corrected to start radiative decay following the time offset for all sources after the first, as intended.
  8. A repetitious MeIMACCS header line that was being printed during each weather trial was removed. This only occurred when using the Multi-Source option.

9. A coding error in the Threshold model was corrected. An error was found in the calculation of the fraction of years to be added to the maximum number of exposure years when using the Threshold model. This error had very little to no effect on results.
10. Corrected potential errors when calculating values for the Population Movement requests Type E results. Because of different initializations or because the variables were not explicitly defined in the FORTRAN code, the calculated Population Movement values could be slightly different between the release version and the debug version. To eliminate these differences, the variables are now defined explicitly and the "implicit none" FORTRAN directive is used.
11. Calculations of the Overall results when using the Time weighting factor option were corrected. Each cohort population is no longer being multiplied by the weight factor. The Early cohorts now show the results using 100% of the population for each cohort, as intended.

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MODIFICATIONS MADE TO CREATE MACCS 4.1.0.0 FROM MACCS 4.0.0.0

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**Enhancements:**

1. Added Ramsdell and Fosmire plume meander model and additional capabilities to the Regulatory Guide 1.145 plume meander model. Additional forms with coefficients for those models were added. This provides options in MACCS to simulate or bound nearfield calculations performed with other codes.  
Added Plume source options of point source and area source.  
Added Trapping/Downwash options with more flexibility on state of plume after trapping/downwash.
2. Modified the BUILDH minimum value and dispersion table DISTANCE range and number of allowed values in the table.
  - a. Change BUILDH to now have a minimum value of 0.0.
  - b. Changes to Dispersion table: Allow DISTANCE values to have the range of 0.001 up to 1E20 and for the dispersion table to have up to 99 values (rows) (i.e. NUM\_DIST will now have a maximum value of 99).
3. The EARLY Projective Peak Dose output result type has been added. This is a potential peak dose output option involving a moving window to define the largest dose at a given location over some user defined time period. Each dose will be calculated running from the time a plume arrives at a grid element to the end of the given time period. Then the maximum of the sum of the different plume releases will be set as the peak dose. The user will define an organ and a time period. The output will be printed for each radius. (Same as Peak Dose - type A output). Calculations will be done for all cohorts and include output in the Overall cohort. No CHRONC cohort output or calculations are done. The calculations will assume no population movement but will include all sheltering defined for a given cohort.

4. Added Crop Disposal cost to GDP (RDEIM) economic model calculations and output. This would include both Milk and Crop Disposal cost.
5. Optional UTC Time Keyword has been added to the list of optional keywords available to be used in a weather file. The optional keyword /UTCTIM with a UTC time value is to be used in weather files to designate the local UTC time zone used to generate the file. MACCS will then adjust the requested day and hour for each calculation to the corresponding UTC time in the weather file. This allows weather files to be created using weather data that are based in UTC time. This is especially useful when combined with HYSPLIT data files run in UTC time. The MACCS weather file must have the same basis when using the HYSPLIT ATD option. Furthermore, this ensures time synchronization between local time and UTC time when switching between Gaussian and HYSPLIT ATD calculations.
6. Optional Maximum Mixing Height Format Keyword has been added to the list of optional keywords available to be used in a weather file. The optional keyword /MIXHGT is to be used in a weather files to designate that the new format is being used. If the keyword /MIXHGT appears in the weather file (no value is associated with this keyword) then the maximum mixing height values will appear as a real number at the end of each time period line with at least one blank space between it and the rain measurement value. No seasonal values will appear in the last line of a weather file that uses the optional keyword /MIXHGT in it.

When a weather file contains the new optional Maximum Mixing Height Format, the following will be done.

DAY\_ONLY option: The maximum mixing height value for a given day will be used for all time periods of that day.

If the ATD calculation spans multiple days, the next day's maximum mixing height is compared, and the larger value is used.

DAY\_AND\_NIGHT option: The current time period maximum mixing height will be used. If the ATD calculation spans multiple time periods, the next time period maximum mixing height is compared, and the larger value is used.

7. Added an optional EARLY input CARD which defines a flag to direct MACCS2 to delete the Threshold Dose Factor Binary file that is created when using the Threshold model. The EARLY input CARD name is CHDDOSFAC01. If CHDDOSFAC01 has the value of .TRUE.: Then, if the file already exists and is usable, MACCS will read in the values of the file and then delete it. If the file does not exist then MACCS will only create the calculations to be used and not save them to a file. If CHDDOSFAC01 has the value of .FALSE.: Then, if the file exists and is usable MACCS will read in the values of the file and not delete it. If the file does not exist

then MACCS will create the calculations to be used and then create and save them to the file.

If the optional CARD is not defined then the flag will be assumed to be .FALSE..

8. Added an optional EARLY input CARD called CHR\_FILE001 whose value defines the path and name of the Threshold Dose Factor Binary file used by the Threshold model. Previously the file was hard coded with the name ChrndfFactors.bin and was written to the project input directory. If the EARLY input CARD is not defined then the default name will be set to ChrndfFactors.bin and the directory will be the project input directory.
9. In the previous version, the .plum animation file created by MACCS and read by the AniMACCS program only included data up to the center of the last ring. The data in the .plum file has now been increased to include the outer most radius of the last ring. Therefore, when running AniMACCS with the new .plum file the plumes travel to the outer most radius of the last ring before disappearing.
10. The cloudshine factors table has been updated to account for values outside of the current table, and extrapolation has been made clearer in the code.

#### **Bug Fixes:**

1. Corrected the DAY\_ONLY option, when not using a weather file with seasonal maximum mixing heights, to not allow the maximum mixing height to decrease. If the next time period's seasonal maximum mixing height is less than the previous time period seasonal value, then the previous time period seasonal value will be used when calculation span between multiple seasons.
2. When the number of types of cancer that can result from acute exposure (MACCS variable NUMACA) was allowed to be 0 to 30 and dynamically allocated, some MACCS array variables (i.e. CANFAT, CANINJ, CCANFA and CCANIN) whose array size is indexed to the size of NUMACA, did not get changed from having the value 10 hard coded. This affects the new Sample problem Point Estimates LNT. Any Latent cancer parameter defined beyond the 10<sup>th</sup> can have a higher or lower incorrect value calculated for it. This will also affect the values of the total Cancer deaths, Health Effects. The error has now been corrected and the above array variables are now dynamically allocated correctly.
3. A potential ATMOS error was corrected involving the possibility of the weather hour exceeding the maximum allowed value. It was found that cases using the user defined weather option could fail by exceeding this value and other cases potentially could have failed also.
4. Modified the calculation of the maximum plume rise calculation for the new Briggs model option. The code now calculates up to the 11<sup>th</sup> order estimate. Previously, only the 2<sup>nd</sup> order estimate was calculated.
5. Updated error messages about the regional disruption period compared to LASTACUM defined in the COMIDA2 file when using the RDEIM model:  
New message string now says:

*"With current settings of the RDEIM economic model, the total regional disruption period will be XX years (ENDEMP + DUR\_INPHAS + Time for maximum possible level of decontamination + ECON\_RGDR) rounded up to the next whole year."*

6. The Dose Projection Period (DDPEMP) maximum value is now limited to the value of ENDEMP.
7. A potential error was corrected involving the possibility of not having a defined wind direction when plume releases are still occurring after boundary weather is used. A new MACCS variable has been defined for the Boundary wind direction. This value is set to the value of the wind direction of the last defined weather hour. This value is needed when conditions occur and boundary weather is being used and plume releases are still occurring. For example, in the case of user defined weather, there are only 200 hours of defined weather but plume releases could be occurring after 200 hours.
8. An error in the allocation of memory when using the HYSPLIT model with Multi-Source option was found that was causing MACCS to crash. This has now been corrected.
9. The last 2 data points printed to the plume movement animation output file (.plum) were incorrect. It had the plume traveling too slowly. This has been corrected. The calculation now uses either the previous speed recorded or the boundary weather speed if boundary weather conditions have occurred.
10. Changed units printed to the text output file for EARLY Population Dose (Type 5) results and CHRONC Population Dose (Type 9) results from just "Sv" to the correct units of "person-Sv".
11. Previously, MACCS required an OALARM value in the cases of a non-evacuating cohort or if the REFPNT value was set to PLUME ARRIVAL. An OALARM value is not needed for either of these cases. Therefore, the MACCS code has been changed to now not require an OALARM value under these conditions.
12. In previous versions, if a CAN/INJ health effect name was selected for an Average Individual Risk result type, MACCS gives an error message stating that type of request is invalid. But MACCS documentation states cancer injuries (CAN/INJ) are allowed in Average Individual Risk (Type 4) result requests. Therefore, MACCS code has now been changed to allow calculations of CAN/INJ health effect results. Also, now allowing and calculating cancer injuries total (CAN INJ/TOTAL) for Average Individual Risk (Type 4) output.
13. Updated the GDP (RDEIM) economic model depreciation calculations to be the following:

Non-Farmland depreciation =  $VNFRM * FRNFIM * (1 - \text{EXP}(-DPRATE*T))$

Farmland depreciation =  $VFRM * FRFIM * (1 - \text{EXP}(-DPRATE*T))$

14. Corrected an error when using the HYSPLIT model and if DRYDEP = FALSE and WETDEP = FALSE. An error was causing all doses to be zero because the code was only looking at ground concentrations and all ground concentrations will be zero if DRYDEP = FALSE and WETDEP = FALSE. The code has now been fixed to also look at air concentrations. Therefore, doses now have positive values when they should.
15. The check sigma routine has been updated to be consistent with off-centerline air concentration routine. Needed to remove virtual source distance from the calculation and reduce the distance at which it starts checking from 10 km to 1km. Also, updated the error message to reflect the entire plume instead of just half for clarity.
16. Errors were found when running MACCS with the weather option stratified random sampling (METCOD = 5) while using a met file with multiple years of weather data.  
The following errors were found and have now been corrected:
  - a. Keywords were not being read correctly.
  - b. All data years in the multi-year met file must be in the same format and have the same keywords and corresponding values. This was not being checked and verified. Error messages to be printed if verification fails.
  - c. When using a multi-year file, a memory allocation error occurred causing MACCS to crash.
  - d. Results values for the years after year 1 were not being stored correctly.