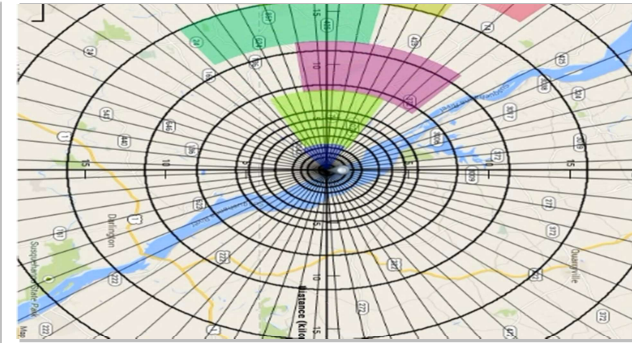
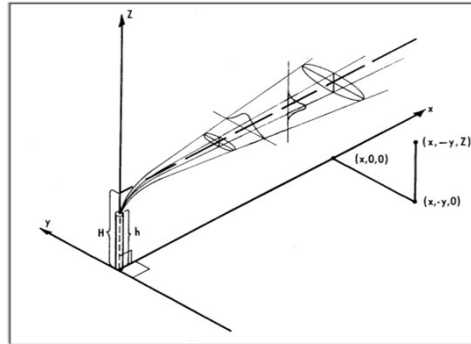
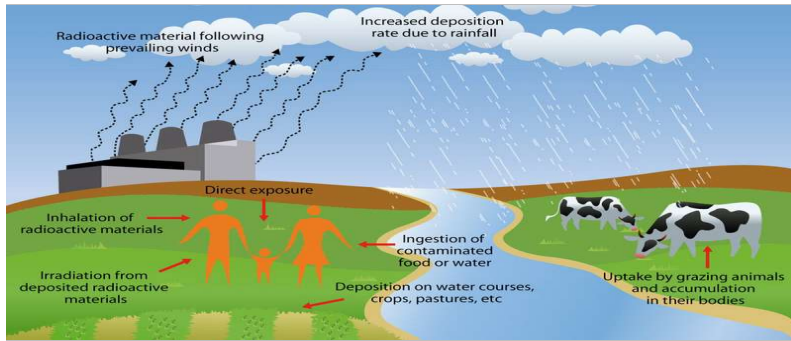


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# Verification and Validation of MACCS ATMOS Model

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# Introduction

- Background
  - OI PRM-012
  - MD 11.7 (NUREG/BR-0167)
  - DOE Toolbox
- Approach
  - P-301 example problems
  - MACCS Model Description Document (NUREG/CR-4691)
  - WinMACCS User's Guide
  - Engineering Equation Solver (EES)
  - $\leq 1\%$  goal



# Approach

Test Case	Description	
1	Verify atmospheric dispersion	ATMOS
2a	Verify radioactive decay	ATMOS
2b	Verify atmospheric stability (IBDSTB)	ATMOS
2c	Verify wind speed (BNDWND)	ATMOS
3a	Verify dry deposition (VDPOS)	ATMOS
3b	Verify wet deposition (CWASH1, CWASH2, BNDRAN)	ATMOS
3c	Verify simultaneous dry and wet deposition	ATMOS
4a	Verify Cs-137 cloudshine, groundshine, inhalation, resuspension	EARLY
4b	Verify Cs-137 with different organ	EARLY
5a	Verify I-132 cloudshine, groundshine, inhalation, resuspension	EARLY
5b	Verify I-132 with different organ	EARLY
6	Verify Skin Dose	EARLY



# Engineering Equation Solver (EES)



- Similar to TK Solver, Mathematica, and PTC Mathcad
- EES is a general equation-solving program that can numerically solve thousands of coupled non-linear algebraic and differential equations
  - The program can also be used to solve differential and integral equations, do optimization, provide uncertainty analyses, perform linear and non-linear regression, convert units, check unit consistency, and generate publication-quality plots.
- NRC applications
  - Analyze ESBWR control room habitability and US-APWR GS-191 NPSH



# Atmospheric Dispersion

Input Parameters Case 1	Value
Building Width (m)	37
Building Height (m)	60
Release Time (s)	1800
Wind Speed (m/s)	1
Surface Roughness (cm)	100
Mixing Height (m)	1500
Distance Evaluated (m)	800 and 13000
Half Life of Released Material (s)	9.49E+08
Release Amount (Ci)	1
Release Height (m)	0
Height of Person (m)	0
Atmospheric Stability	F

## Release 1 Ci of Cs-137

Test Case 1	Hand Calc	MACCS	% Difference
<b>at 800m</b>			
sigma_y (m)	44.1	44.1	0
sigma_z (m)	38.7	38.7	0
GL AIRCON (Bq-s/m <sup>3</sup> )	6.90E+06	6.90E+06	0
<b>at 13000m</b>			
sigma_y (m)	472	472	0
sigma_z (m)	127	127	0
GL AIRCON (Bq-s/m <sup>3</sup> )	1.96E+05	1.96E+05	0



# Radioactive Decay

Input Parameters Case 2a	Value
Building Width (m)	56.5
Building Height (m)	38.3
Release Time (s)	7200
Wind Speed (m/s)	4
Surface Roughness (cm)	1
Mixing Height (m)	500
Distance Evaluated (m)	9100
Half Life of Released Material (s)	8.28E+03
Release Amount (Ci)	10
Release Height (m)	0
Height of Person (m)	0
Atmospheric Stability	C

I-132 released instead of Cs-137

Test Case 2			
A: C Stability	Hand Calc	MACCS	% Difference
sigma_y (m)	1470	1470	0
sigma_z (m)	396	396	0
GLAIRCON (Bq-s/m <sup>3</sup> )	2.48E+04	2.48E+04	0



# Atmospheric Stability (IBDSTB)

Input Parameters Case 2b	Values
Building Width (m)	56.5
Building Height (m)	38.3
Release Time (s)	7200
Wind Speed (m/s)	4
Surface Roughness (cm)	1
Mixing Height (m)	500
Distance Evaluated (m)	9100
Half Life of Released Material (s)	8.28E+03
Release Amount (Ci)	10
Release Height (m)	0
Height of Person (m)	0
Atmospheric Stability	F

Atmospheric stability changed from C to F

B: F stability	Hand Calc	MACCS	% Difference
sigma_y (m)	513	513	0
sigma_z (m)	45	45	0
GLAIRCON (Bq-s/m <sup>3</sup> )	5.76E+05	5.76E+05	0



# Wind Speed (BNDWND)

Input Parameters Case 2c	Values
Building Width (m)	56.5
Building Height (m)	38.3
Release Time (s)	7200
Wind Speed (m/s)	4
Surface Roughness (cm)	1
Mixing Height (m)	500
Distance Evaluated (m)	9100
Half Life of Released Material (s)	8.28E+03
Release Amount (Ci)	10
Release Height (m)	0
Height of Person (m)	0
Atmospheric Stability	F

Wind speed changed from 4 m/s to 1 m/s

C: Wind = 1 m/s	Hand Calc	MACCS	% Difference
sigma_y (m)	513	513	0
sigma_z (m)	45	45	0
GLAIRCON (Bq-s/m <sup>3</sup> )	1.30E+06	1.30E+06	0



# Dry Deposition (VDPOS)

Input Parameters Case 3a	Values
Building Width (m)	37
Building Height (m)	60
Release Time (s)	1800
Wind Speed (m/s)	1
Surface Roughness (cm)	100
Mixing Height (m)	1500
Distance Evaluated (m)	800 and 13000
Half Life of Released Material (s)	9.49E+08
Release Amount (Ci)	1
Release Height (m)	0
Height of Person (m)	0
Dry Depositon Velocity (m/s)	0.01
Atmospheric Stability	F

## Test case 1 with dry deposition

Test Case 3	Hand Calc	MACCS	% Difference
<b>A: Dry Deposition</b>			
<b>800m</b>			
sigma_y (m)	44.1	44.1	0
sigma_z (m)	38.7	38.7	0
GL AIRCON (Bq-s/m <sup>3</sup> )	5.70E+06	5.70E+06	0
GRNCON (Bq/m <sup>2</sup> )	5.70E+04	5.70E+04	0
<b>13000m</b>			
sigma_y (m)	472	472	0
sigma_z (m)	127	127	0
GL AIRCON (Bq-s/m <sup>3</sup> )	5.00E+04	5.00E+04	0
GRNCON (Bq/m <sup>2</sup> )	5.00E+02	5.00E+02	0



# Wet Deposition (CWASH1, CWASH2, BNDTRAN)

Input Parameters Case 3b	Values
Building Width (m)	37
Building Height (m)	60
Release Time (s)	1800
Wind Speed (m/s)	1
Surface Roughness (cm)	100
Mixing Height (m)	1500
Distance Evaluated (m)	800 and 13000
Half Life of Released Material (s)	9.49E+08
Release Amount (Ci)	1
Release Height (m)	0
Height of Person (m)	0
Dry Depositon Velocity (m/s)	0
Precipitation Rate (mm/hr)	25.4
Atmospheric Stability	F

Test case 1 with wet deposition

B: Wet Deposition			
<b>800m</b>			
sigma_y (m)	44.1	44.1	0
sigma_z (m)	38.7	38.7	0
GL AIRCON (Bq-s/m <sup>3</sup> )	2.52E+06	2.52E+06	0
GRNCON (Bq/m <sup>2</sup> )	1.54E+05	1.54E+05	0
<b>13000m</b>			
sigma_y (m)	472	472	0
sigma_z (m)	127	127	0
GL AIRCON (Bq-s/m <sup>3</sup> )	1.45E-02	1.45E-02	0
GRNCON (Bq/m <sup>2</sup> )	2.91E-03	2.90E-03	-0.34482759



# Wet and Dry Deposition

Input Parameters Case 3c	Values
Building Width (m)	37
Building Height (m)	60
Release Time (s)	1800
Wind Speed (m/s)	1
Surface Roughness (cm)	100
Mixing Height (m)	1500
Distance Evaluated (m)	800 and 13000
Half Life of Released Material (s)	9.49E+08
Release Amount (Ci)	1
Release Height (m)	0
Height of Person (m)	0
Dry Depositon Velocity (m/s)	0.01
Precipitation Rate (mm/hr)	25.4
Atmospheric Stability	F

Test case 1 with dry and wet deposition

C: Dry and Wet Deposition	Hand Calc	MACCS	% Difference
<b>800m</b>			
sigma_y (m)	44.1	44.1	0
sigma_z (m)	38.7	38.7	0
GLAIRCON (Bq-s/m <sup>3</sup> )	2.08E+06	2.08E+06	0
GRNCON (Bq/m <sup>2</sup> )	1.48E+05	1.48E+05	0
<b>13000m</b>			
sigma_y (m)	472	472	0
sigma_z (m)	127	127	0
GLAIRCON (Bq-s/m <sup>3</sup> )	3.59E-03	3.59E-03	0
GRNCON (Bq/m <sup>2</sup> )	7.54E-04	7.54E-04	0



# EARLY Health Effects - Cloudshine, Groundshine, Inhalation, Resuspension

Input Parameters Case 4a	Values
Building Width (m)	37
Building Height (m)	60
Release Time (s)	1800
Wind Speed (m/s)	1
Surface Roughness (cm)	100
Mixing Height (m)	1500
Distance Evaluated (m)	800 and 13000
Half Life of Released Material (s)	9.49E+08
Release Amount (Ci)	1
Release Height (m)	0
Height of Person (m)	0
Dry Depositon Velocity (m/s)	0.01
Atmospheric Stability	F

**Cs-137** dry deposition, acute dose to **red marrow**

Test Case 4a	Hand Calc	MACCS	% Difference
<b>800m</b>			
A-RED MARR GRD (Sv)	6.80E-09	6.78E-09	-0.29
A-RED MARR CLD (Sv)	9.54E-12	9.54E-12	0
A-RED MARR INH ACU (Sv)	4.73E-07	4.72E-07	-0.21
A-RED MARR RES ACU (Sv)	1.12E-07	1.12E-07	0
<b>13000m</b>			
A-RED MARR GRD (Sv)	5.98E-11	5.95E-11	-0.50
A-RED MARR CLD (Sv)	2.26E-13	2.26E-13	0
A-RED MARR INH ACU (Sv)	4.16E-09	4.15E-09	-0.24
A-RED MARR RES ACU (Sv)	9.82E-10	9.79E-10	-0.31



# EARLY Health Effects - Cloudshine, Groundshine, Inhalation, Resuspension

Input Parameters Case 4b	Values
Building Width (m)	37
Building Height (m)	60
Release Time (s)	1800
Wind Speed (m/s)	1
Surface Roughness (cm)	100
Mixing Height (m)	1500
Distance Evaluated (m)	800 and 13000
Half Life of Released Material (s)	9.49E+08
Release Amount (Ci)	1
Release Height (m)	0
Height of Person (m)	0
Dry Depositon Velocity (m/s)	0.01
Atmospheric Stability	F

**Cs-137** dry deposition, acute dose to **lungs**

<b>Test Case 4b</b>			
<b>800m</b>			
A-LUNG GRD (Sv)	7.66E-09	7.64E-09	-0.26
A-LUNG CLD (Sv)	1.12E-11	1.12E-11	0
A-LUNG INH ACU (Sv)	2.42E-07	2.42E-07	0
A-LUNG RES ACU (Sv)	5.72E-08	5.71E-08	-0.18
<b>13000m</b>			
A-LUNG GRD (Sv)	6.74E-11	6.71E-11	-0.45
A-LUNG CLD (Sv)	2.65E-13	2.64E-13	-0.38
A-LUNG INH ACU (Sv)	2.13E-09	2.12E-09	-0.47
A-LUNG RES ACU (Sv)	5.03E-10	5.01E-10	-0.40



# EARLY Health Effects - Cloudshine, Groundshine, Inhalation, Resuspension

Input Parameters Case 5a	Values
Building Width (m)	37
Building Height (m)	60
Release Time (s)	1800
Wind Speed (m/s)	1
Surface Roughness (cm)	100
Mixing Height (m)	1500
Distance Evaluated (m)	800 and 13000
Half Life of Released Material (s)	9.49E+08
Release Amount (Ci)	1
Release Height (m)	0
Height of Person (m)	0
Dry Depositon Velocity (m/s)	0.01
Atmospheric Stability	F

I-132 dry deposition, acute dose to red marrow

Test Case 5a	Hand Calc	MACCS	% Difference
<b>800m</b>			
A-RED MARR GRD (Sv)	1.28E-06	1.28E-06	0
A-RED MARR CLD (Sv)	1.44E-07	1.44E-07	0
A-RED MARR INH ACU (Sv)	1.41E-08	1.41E-08	0
A-RED MARR RES ACU (Sv)	1.61E-10	1.61E-10	0
<b>13000m</b>			
A-RED MARR GRD (Sv)	4.08E-09	4.04E-09	-0.99
A-RED MARR CLD (Sv)	1.23E-09	1.23E-09	0
A-RED MARR INH ACU (Sv)	4.48E-11	4.46E-11	-0.45
A-RED MARR RES ACU (Sv)	5.11E-13	5.10E-13	-0.20



# EARLY Health Effects - Cloudshine, Groundshine, Inhalation, Resuspension

Input Parameters Case 5b	Values
Building Width (m)	37
Building Height (m)	60
Release Time (s)	1800
Wind Speed (m/s)	1
Surface Roughness (cm)	100
Mixing Height (m)	1500
Distance Evaluated (m)	800 and 13000
Half Life of Released Material (s)	9.49E+08
Release Amount (Ci)	1
Release Height (m)	0
Height of Person (m)	0
Dry Depositon Velocity (m/s)	0.01
Atmospheric Stability	F

**I-132** dry deposition, acute dose to **lungs**

Test Case 5b			
<b>800m</b>			
A-LUNG GRD (Sv)	1.25E-06	1.25E-06	0
A-LUNG CLD (Sv)	1.47E-07	1.47E-07	0
A-LUNG INH ACU (Sv)	4.44E-08	4.44E-08	0
A-LUNG RES ACU (Sv)	5.07E-10	5.07E-10	0
<b>13000m</b>			
A-LUNG GRD (Sv)	3.98E-09	3.95E-09	-0.76
A-LUNG CLD (Sv)	1.25E-09	1.25E-09	0
A-LUNG INH ACU (Sv)	1.41E-10	1.40E-10	-0.71
A-LUNG RES ACU (Sv)	1.61E-12	1.60E-12	-0.62



# Skin Dose

Input Parameters Case 6	Values
Building Width (m)	37
Building Height (m)	60
Release Time (s)	1800
Wind Speed (m/s)	1
Surface Roughness (cm)	100
Mixing Height (m)	1500
Distance Evaluated (m)	800 and 13000
Half Life of Released Material (s)	9.49E+08
Release Amount (Ci)	1
Release Height (m)	0
Height of Person (m)	0
Dry Depositon Velocity (m/s)	0.01
Atmospheric Stability	F

I-132 dry deposition, acute dose to skin

Test Case 6	Hand Calc	MACCS	% Difference
800m			
A-SKIN	8.86E-05	8.88E-05	0.24
13000m			
	7.79E-07	7.80E-07	0.03



# Conclusion

- Matrix of test cases developed to assess key inputs and outputs for ATMOS and EARLY
- Achieved  $\leq 1\%$  deviation between EES and MACCS
- Continued work to implement weather sampling analytic solution in EES
- Documentation in model verification report



# Optional Verification Activities

## EARLY

- Off centerline dose
- Early fatalities and injuries

## Intermediate

- Groundshine and resuspension

## Long Term

- Groundshine, resuspension, and ingestion
- Crop disposal, decontamination, interdiction, condemnation, and restricted crop production
- Lifetime dose for latent cancer risk
- Long term fatalities/injuries

## Protective actions

- Evacuation
- Sheltering
- Relocation

## Economic Costs

- Emergency phase protective action costs
- Intermediate phase protective action costs
- Long term phase protective action costs



# Questions

