



## HABIT

### CODE FOR ASSESSING CONTROL ROOM HABITABILITY

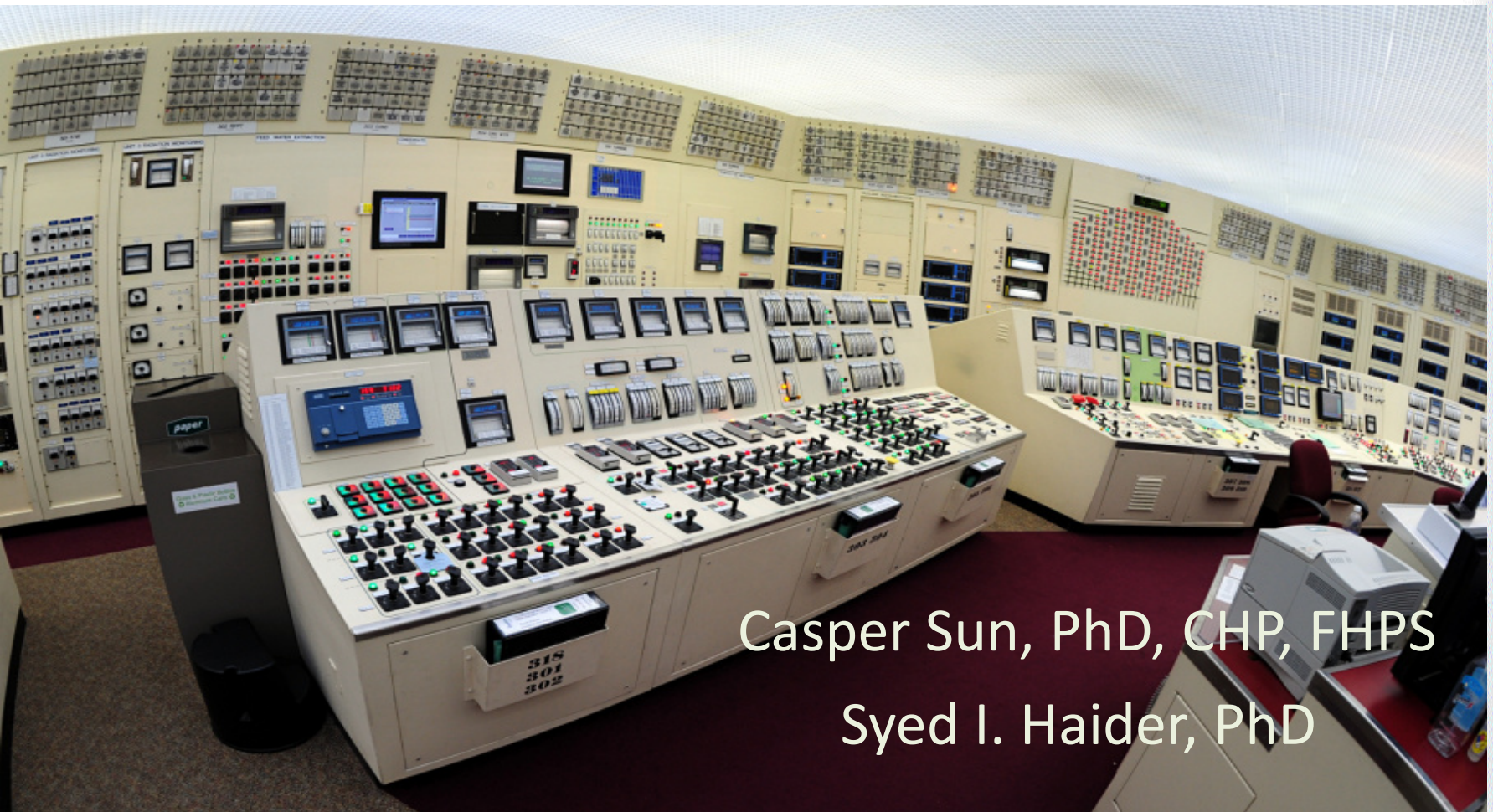
Casper Sun, PhD, CHP, FHPS, MCP

Radiation Protection Branch

Office of Nuclear Regulatory Research

The United States Nuclear Regulatory Commission

# COMPUTER CODE FOR ASSESSING CONTROL ROOM HABITABILITY



Casper Sun, PhD, CHP, FHPS  
Syed I. Haider, PhD

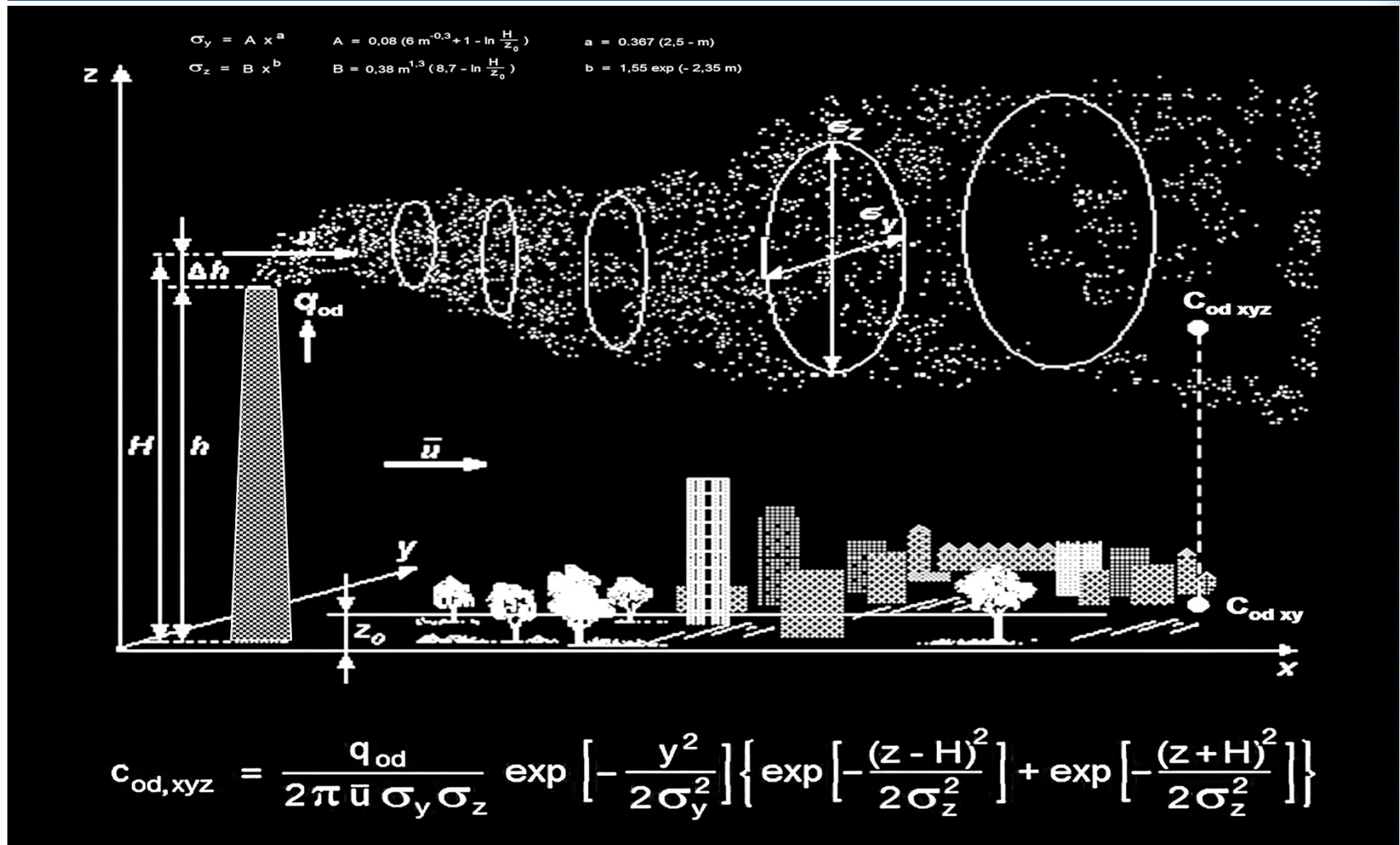
*Prepared for 2015 RAMP first annual meeting,  
Rockville, MD 20852: October 5<sup>th</sup>, 2015*



# Real ATD Pictures

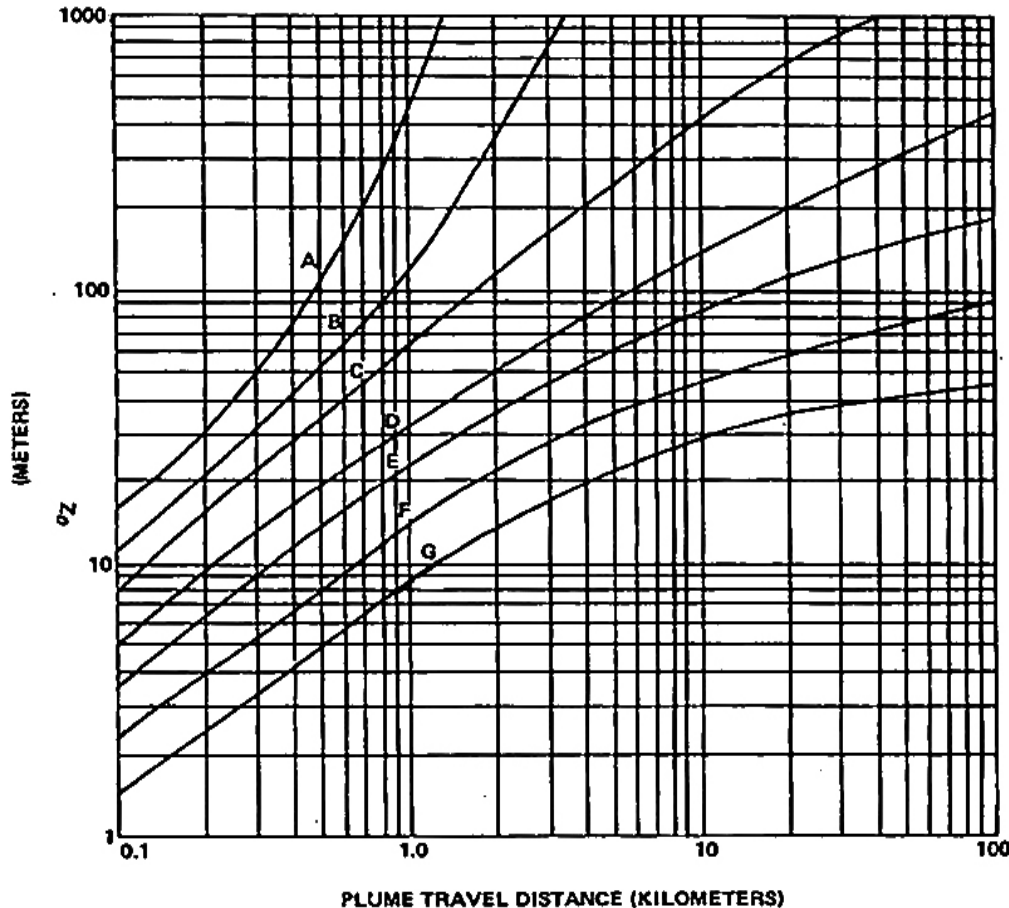


# Basic Gaussian Model





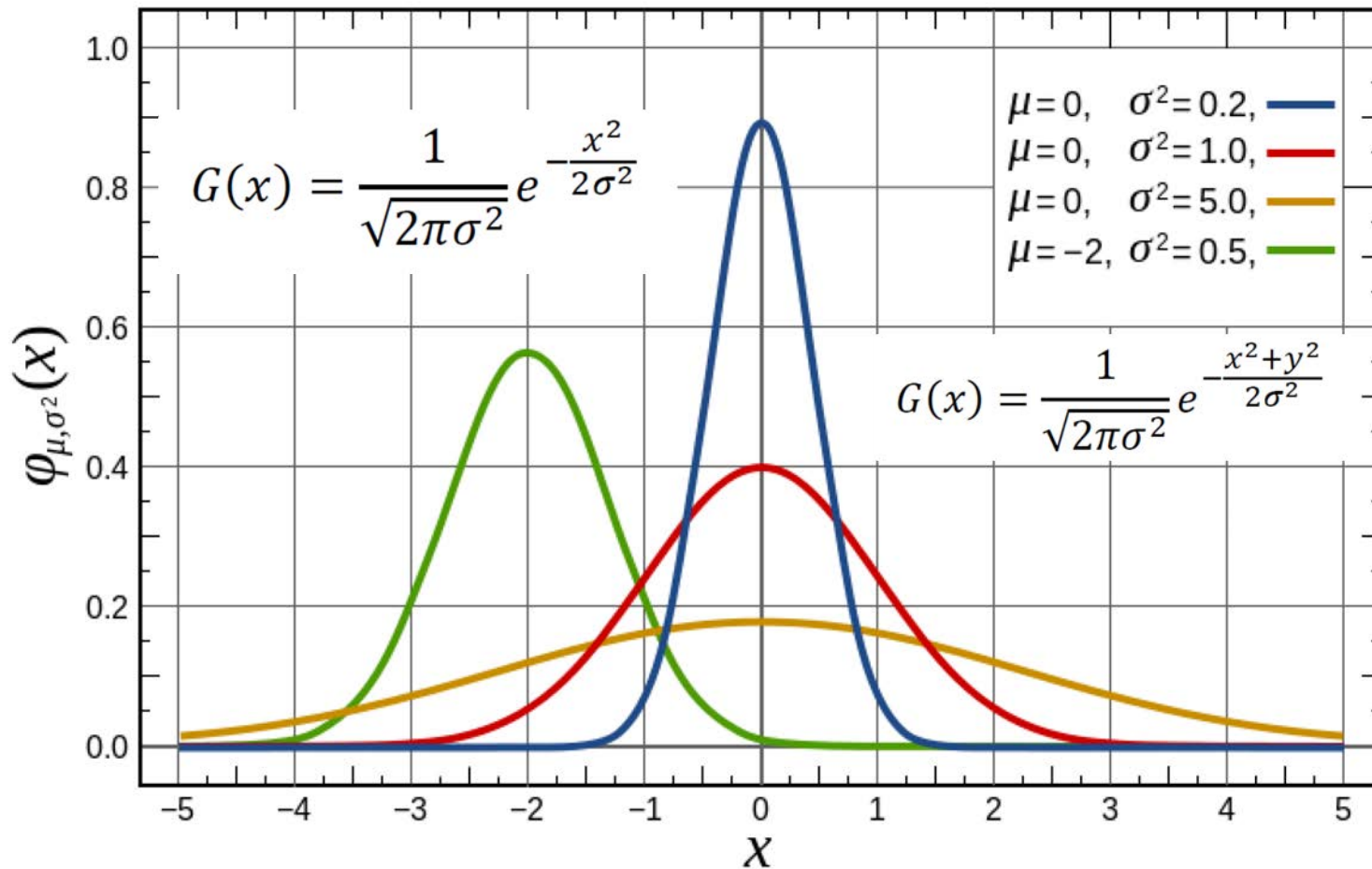
## Height ( $\sigma_z$ ) Vs. Distance

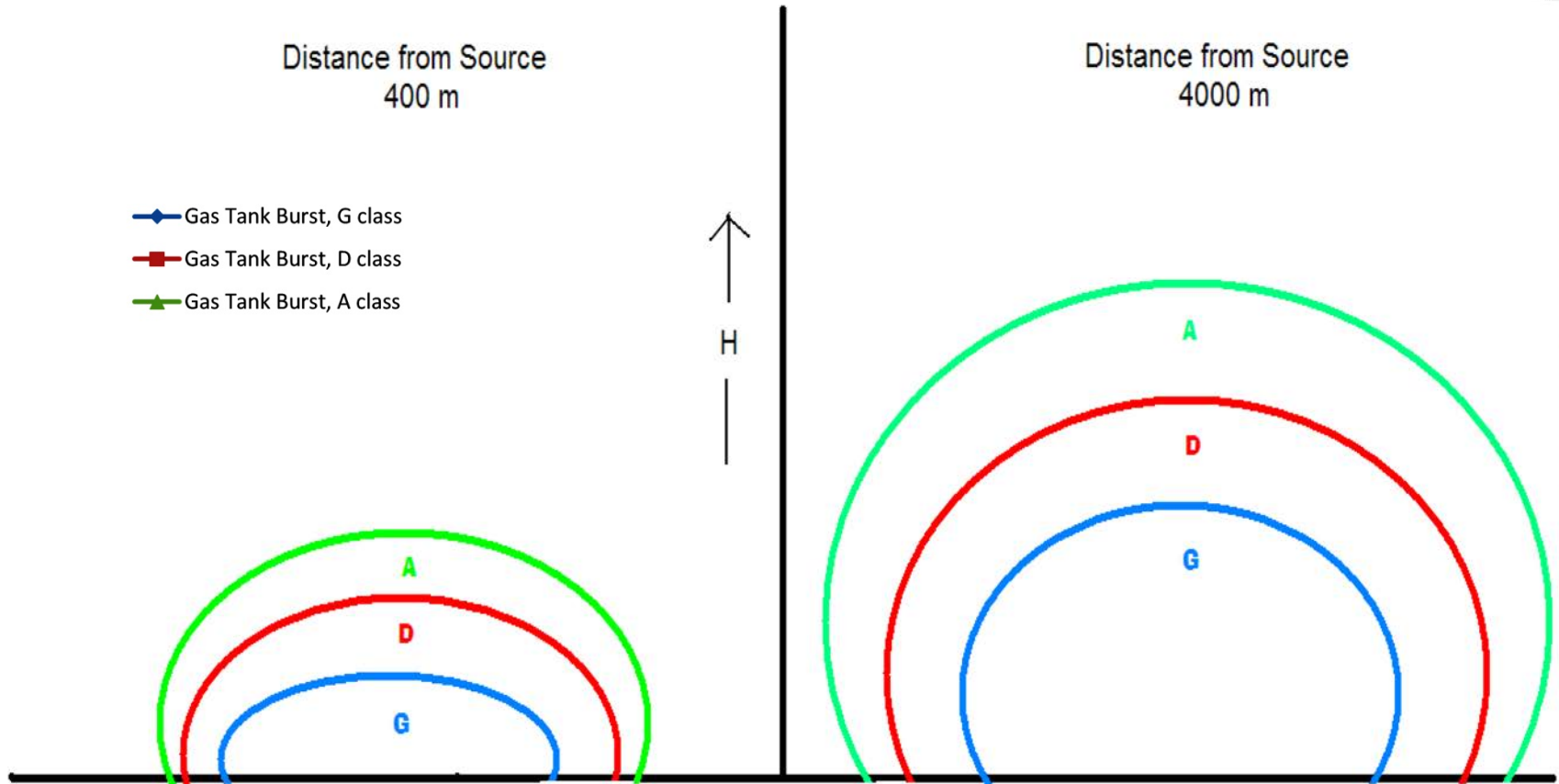


### Concentration in $\sigma_z$ direction:

- Decreases with stability classes (A>F)
- Increases with downwind distance

# Gaussian, Normal Function





Stylized Representation of Changing Puff Volume Limits with Stability Class







# Conservation Equation

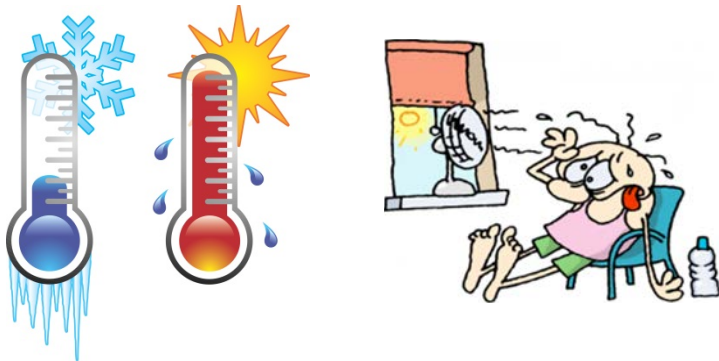
$$\frac{\partial \Phi}{\partial t} + \nabla \cdot (\mathbf{F} + \Phi \mathbf{V}) - H = 0$$



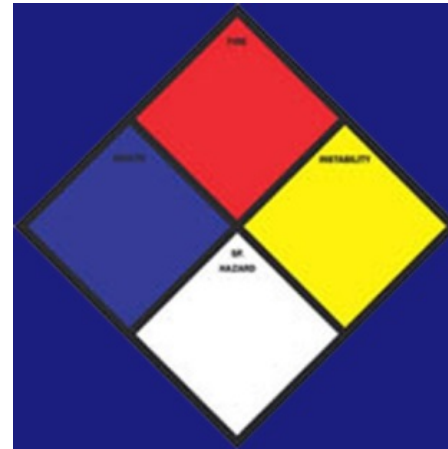
$$C(x, y, z, t) = \frac{Q}{2\pi u \sigma_y \sigma_z} \cdot \exp\left(-\frac{y^2}{2\sigma_y^2}\right) \left[ \exp\left(-\frac{(z - H_{eff})^2}{2\sigma_z^2}\right) + \exp\left(-\frac{(z + H_{eff})^2}{2\sigma_z^2}\right) \right]$$

# Habitability Issues at NRC

## Radiological



## Non-radiological





## Request for Additional Information (RAI) No. 6158

“...the staff posits that since chlorine and sulfuric acid clearly fit the definition of a heavy gas that **ALOHA modeling is the more appropriate program (i.e. as opposed to HABIT) to use for determining main control room habitability.** More specifically, the use of the HABIT Gaussian model may be producing non-conservative results for these two heavy gases. The staff requests that the applicant re-evaluate their findings of FSAR 6.4.4.2 and address the fact that chlorine and sulfuric acid are heavy gases and provide **a comprehensive justification for why the results are appropriate and conservative.**” (November 2011)

# User-Need Request: NRO-2011-007

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## HABIT Code Evaluation and Update

### ACTION ITEMS

#### Phase 1: Re-hosting HABIT to Windows 7 (64-bit)

- Upgrade FORTRAN and modernize GUI
- Build-in tooltips and develop “User’s Manual”

#### Phase 2: Adding Dense-Gas Functions

- Integrate DEGADIS and SLAB to HABIT
- Update TBDs



# Project Overview

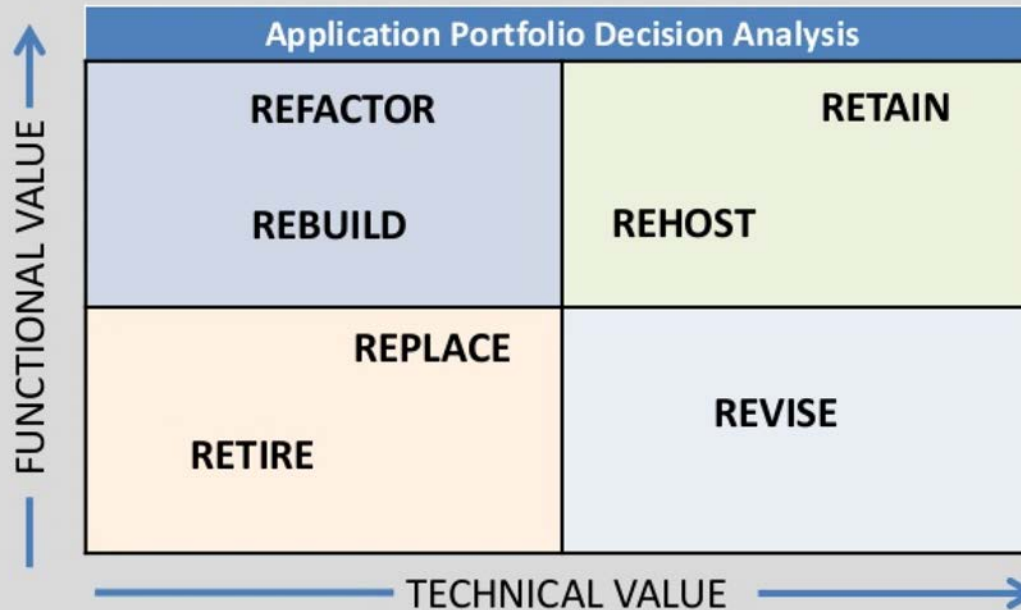
- **Phase I** (June 2014 – Feb. 2015):
  - Repair **HABIT v1.1** FORTRAN source code
  - Develop User Manual and interactive pop-up help screens.
  - Comply Section 508 requirements
  - TRM for **HABIT v1.2** (download and install)
- **Phase II** (April 2015 – Sept. 2016):
  - Integrate DEGADIS and SLAB (D&S) dense gas models
  - GUI and programing completed by April 2016
  - **HABIT v2.0** and revise NUREG/CR-6210 (9/30/16)
  - ATD benchmark and revise RG 1.78 (on the horizon)

**RG 1.78: Evaluating the Habitability of a Nuclear Power Plant Control Room During a Postulated Hazardous Chemical Release (2001)**

# HABIT PHASE-I

June 1, 2014 – February 14, 2015

## Legacy Portfolio Analysis

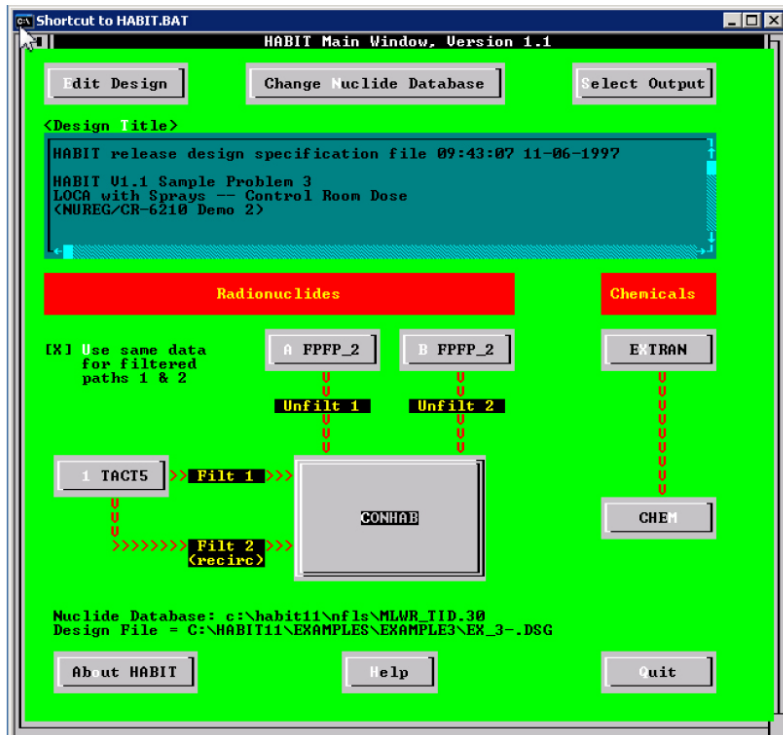




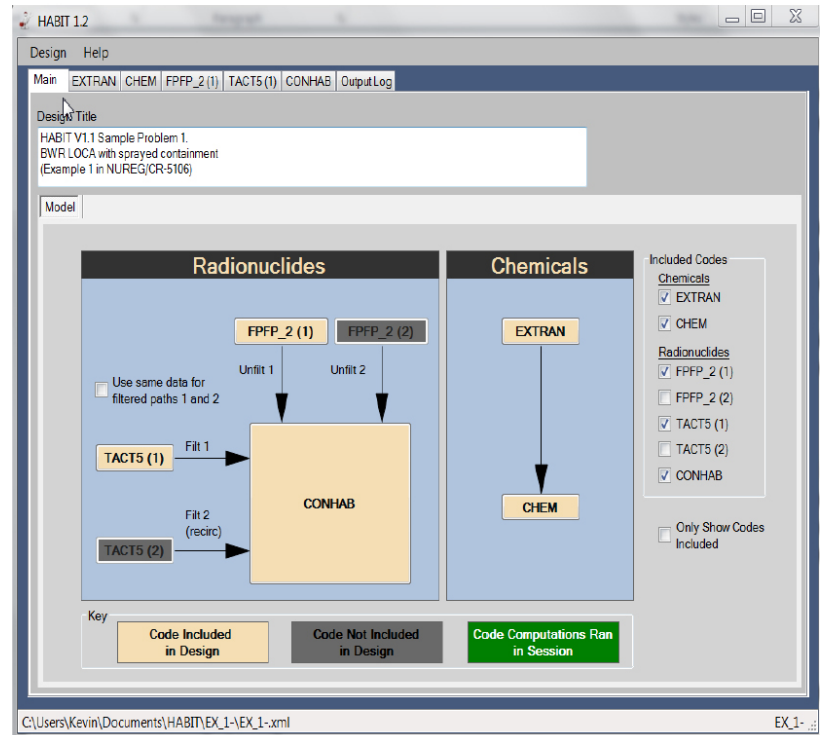
# HABIT MAKEOVER

## from v1.1 to v1.2

Original



New



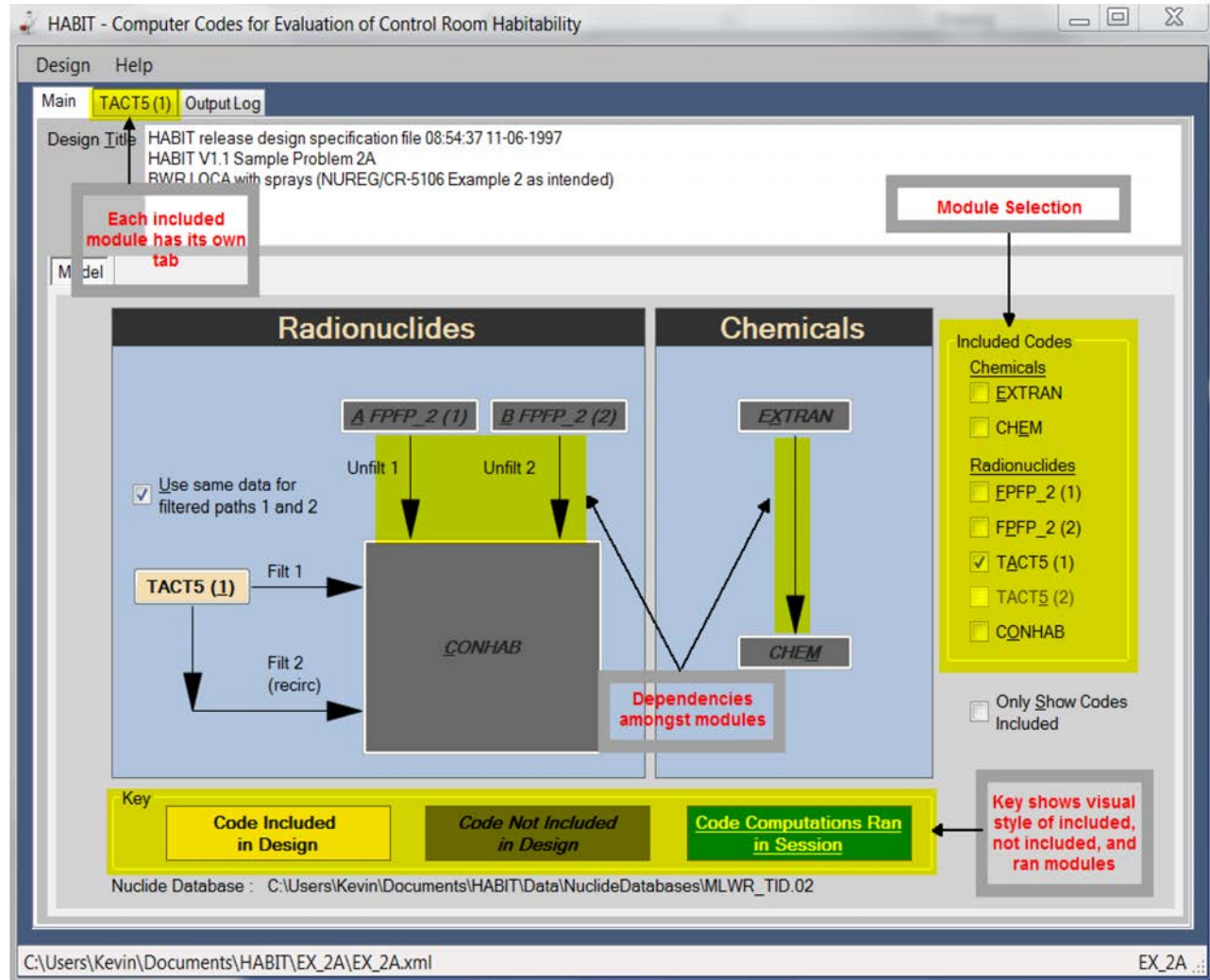
# What's New in HABIT v1.2

- Used Intel Visual FORTRAN compiler for compatibility with Windows 7 (64-bit)
  - I/O are identical as HABIT v1.1
  - Backwards compatible for old designed (.DSG) files and FORTRAN input (.INP) files
- Used new Microsoft .NET technology for graphical user interface (GUI) development
  - Consistent module interface design (tabs)
  - Section 508 Compliance (e.g., color blinder or muted use of color, JAWS accessibility)

# GUI Capabilities

The GUI:

- (1) Depict the relationships between the modules and
- (2) Show modules in the current calculation.





# HABIT v1.2: Tooltips

Tooltips provide a convenient way to see the expected range for fields and provide validations to prevent entering bad data.

Volume (ft<sup>3</sup>)

125000

1300000


35000

303000

**Valid Range**

1E-06 <= value <= 3000000

Number Error

 The entered value is not a valid number. Re-enter a valid number

**Validation Error**

OK

steps | Node Design | Plant Parameters | Time Dependent Data

Volume (ft<sup>3</sup>)

-5

1300000

**Range Validation Warning**

The value -5 is out of range. The valid range is between 1E-06 and 3000000.

## Required Field Warning

EXTRAN Spill Parameters

R Initial Mass (kg c

N

**Field is required**

# HABIT v 1.2

- **Design File**

- DSG (Input) file can be created from scratch or imported from HABIT v1.1 Design Packages
- DSG files are auto-saved when running a module
- Previously saved DSG file is auto-loaded the next time HABIT v1.2 is opened

- **Running Modules**

- Output Log-Tab displays FORTRAN I/O data
- Alerts user when a dependency exists between modules i.e., EXTRAN & CHEM
- “TOOLTIPS” added to interactive check the expected data range and prevent entering bad input

# CHEMical Module

HABIT - Computer Codes for Evaluation of Control Room Habitability

Design Help

Main EXTRAN **CHEM** FPF2\_2 (1) TACT5 (1) CONHAB Output Log

Run Title

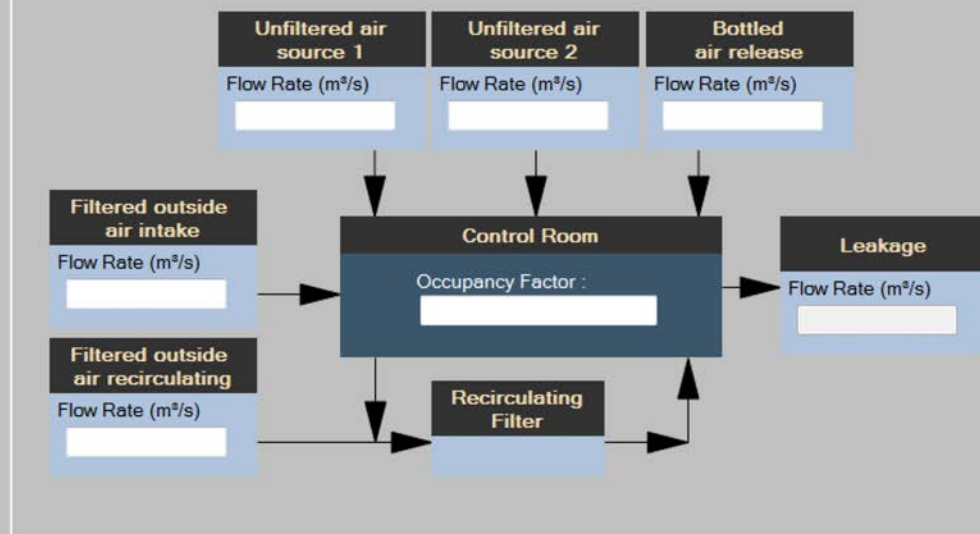
Load Input Clear Values

Run CHEM

Control Room Volume (m<sup>3</sup>)  **No Times Defined**

Control Room Flow

Step #: 1 - + Time (hrs): 0 Delete Time



```
graph TD
    UAS1[Unfiltered air source 1] --> CR[Control Room]
    UAS2[Unfiltered air source 2] --> CR
    BAR[Bottled air release] --> CR
    FOAI[Filtered outside air intake] --> CR
    FOAR[Filtered outside air recirculating] --> CR
    CR --> LF[Leakage]
    CR --> RF[Recirculating Filter]
    RF --> CR
```

The flowchart illustrates the air flow into and out of a control room. It includes inputs for unfiltered air from two sources, bottled air release, filtered outside air intake, and filtered outside air recirculating. The control room's occupancy factor is also a variable. Air flows out through leakage and is recirculated through a filter.

Units

Convert numerical values ?  
☒ Yes  
☐ No

Distance and Volume Units  
☒ Meters and m<sup>3</sup>  
☐ Feet and ft<sup>3</sup>

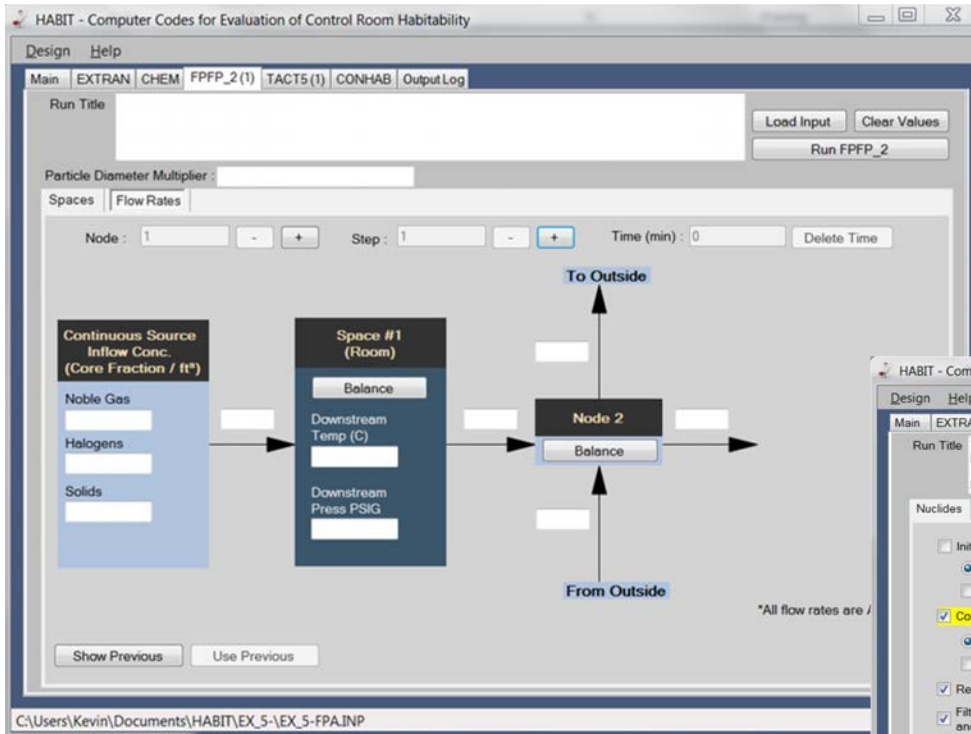
Flow Rate Units  
☒ m<sup>3</sup>/s  
☐ m<sup>3</sup>/min  
☐ ft<sup>3</sup>/s  
☐ ft<sup>3</sup>/min

C:\Users\Kevin\Documents\HABIT\EX\_5-\EX\_5-CH.INP EX\_5-

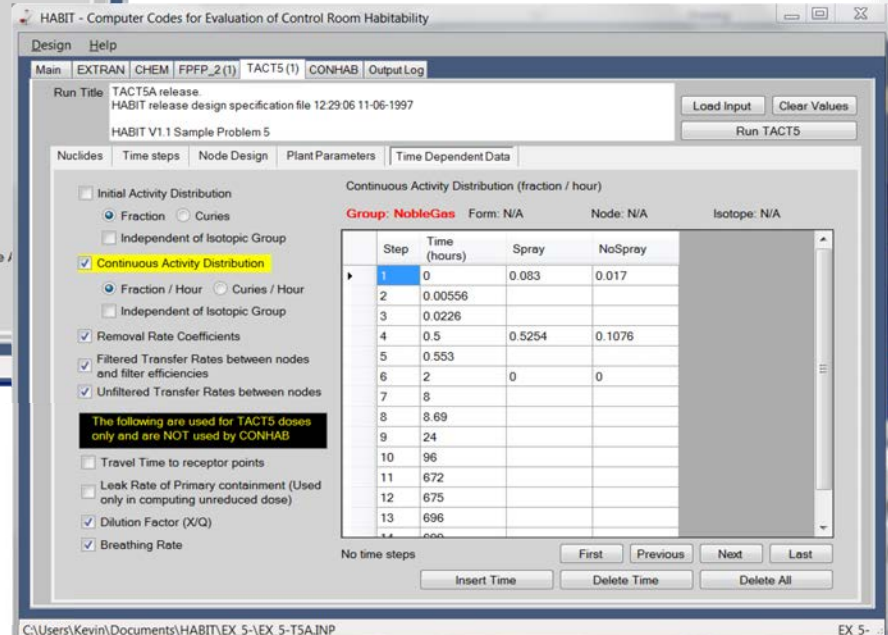


# Radiological Modules

## TACT Module



## FPFP Module



HABIT - Computer Codes for Evaluation of Control Room Habitability

Design Help

Main EXTRAN CHEM FFPF\_2(1) TACT5(1) CONHAB Output Log

Run Title: TACT5A release  
HABIT release design specification file 12-29-06 11-06-1997  
HABIT V1.1 Sample Problem 5

Nuclides Time steps Node Design Plant Parameters Time Dependent Data

☐ Initial Activity Distribution  
☒ Fraction ☐ Curies  
☐ Independent of Isotopic Group  
☒ Continuous Activity Distribution  
☒ Fraction / Hour ☐ Curies / Hour  
☐ Independent of Isotopic Group  
☒ Removal Rate Coefficients  
☒ Filtered Transfer Rates between nodes and filter efficiencies  
☒ Unfiltered Transfer Rates between nodes  
 The following are used for TACT5 doses only and are NOT used by CONHAB  
☐ Travel Time to receptor points  
☐ Leak Rate of Primary containment (Used only in computing unreduced dose)  
☒ Dilution Factor (X/Q)  
☒ Breathing Rate

Continuous Activity Distribution (fraction / hour)

Group: NobleGas Form: N/A Node: N/A Isotope: N/A

Step	Time (hours)	Spray	NoSpray
1	0	0.083	0.017
2	0.00556		
3	0.0226		
4	0.5	0.5254	0.1076
5	0.553		
6	2	0	0
7	8		
8	8.69		
9	24		
10	96		
11	672		
12	675		
13	696		
14	696		

No time steps First Previous Next Last

Insert Time Delete Time Delete All

C:\Users\Kevin\Documents\HABIT\EX\_5-EX\_5-TSA.INP EX\_5-



## FORTRAN modules and I/O data

- Impacts from identified “BUGS” and modifications made in HABIT 1.2
- Precision of reproduced identical results



Compilation and operational steps in the new “User Manual”

# HABIT PHASE-II

April 2015 - Sept 2016

- **Version 2.0 (2016):** Built-in with two most popular DEGADIS and SLAB (D&S) dense gas models
- Align and update TBD documents





# Vertical Dispersion Coefficients ( $\sigma_z$ )

## Differences between $\sigma_z$ used in HABIT and ALOHA codes

Stability Class	A (very unstable)			D (neutral)			G (very stable)		
Wind Speed (m/s)	1	3	5	1	3	5	1	3	5
<b>HABIT <math>\sigma_z</math></b>									
<b>Distance = 400 m</b>	87	97	156	30	52	133	26	50	133
<b>Distance = 4,000 m</b>	1000	1000	1000	86	226	590	40	213	585
<b>ALOHA <math>\sigma_z</math></b>									
<b>Distance = 400 m</b>	83	83	83	15	15	15	4	4	4
<b>Distance = 4,000 m</b>	1000	1000	1000	78	78	78	19	19	19

# Comparison HABIT vs. ALOHA for a Spilled Chlorine Pool Release

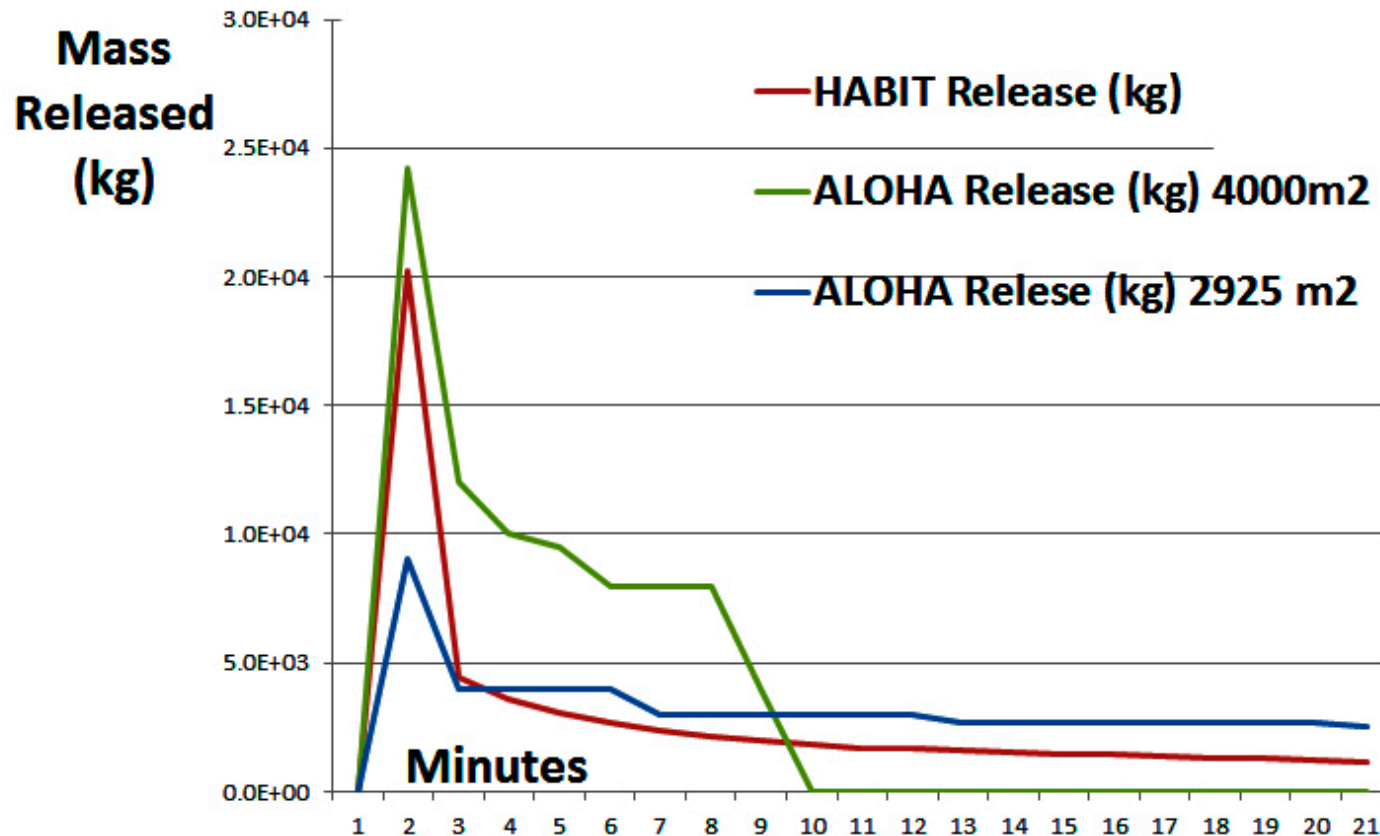


Figure 2. Source: A Spilled Chlorine Pool of 81,650 kg

# Dense Gases Models Validation

Model	Developer	Purpose	Scenarios	Type
ALOHA 5.4.3	EPA/NOAA	Dense gas and neutrally buoyant gas dispersions	Leak from pipeline or tank, evaporating puddle, direct open source	Source-term model
DEGADIS 2.1	University of Arkansas	Dense gas and neutrally buoyant gas dispersions	Elevated or ground-level area source, vertical jet leak	Non-source-term model
HABIT 1.1	PNNL	Neutrally buoyant gas dispersions	Liquid or gas tank burst and leak	Source-term model
SCIPUFF 2.2	Titan Research and Technology	Dense gas and neutrally buoyant gas dispersions	Moving and stack sources, gaseous and particulate materials	Non-source-term model
SLAB	LLNL	Dense gas and neutrally buoyant gas dispersions	Open evaporating pool, horizontal and vertical jet/stack, instantaneous volume liquid sources	Non-source-term model

**Table E.1: Performed by ANL (ANL/EVS/TM-13.3: April 2013)**

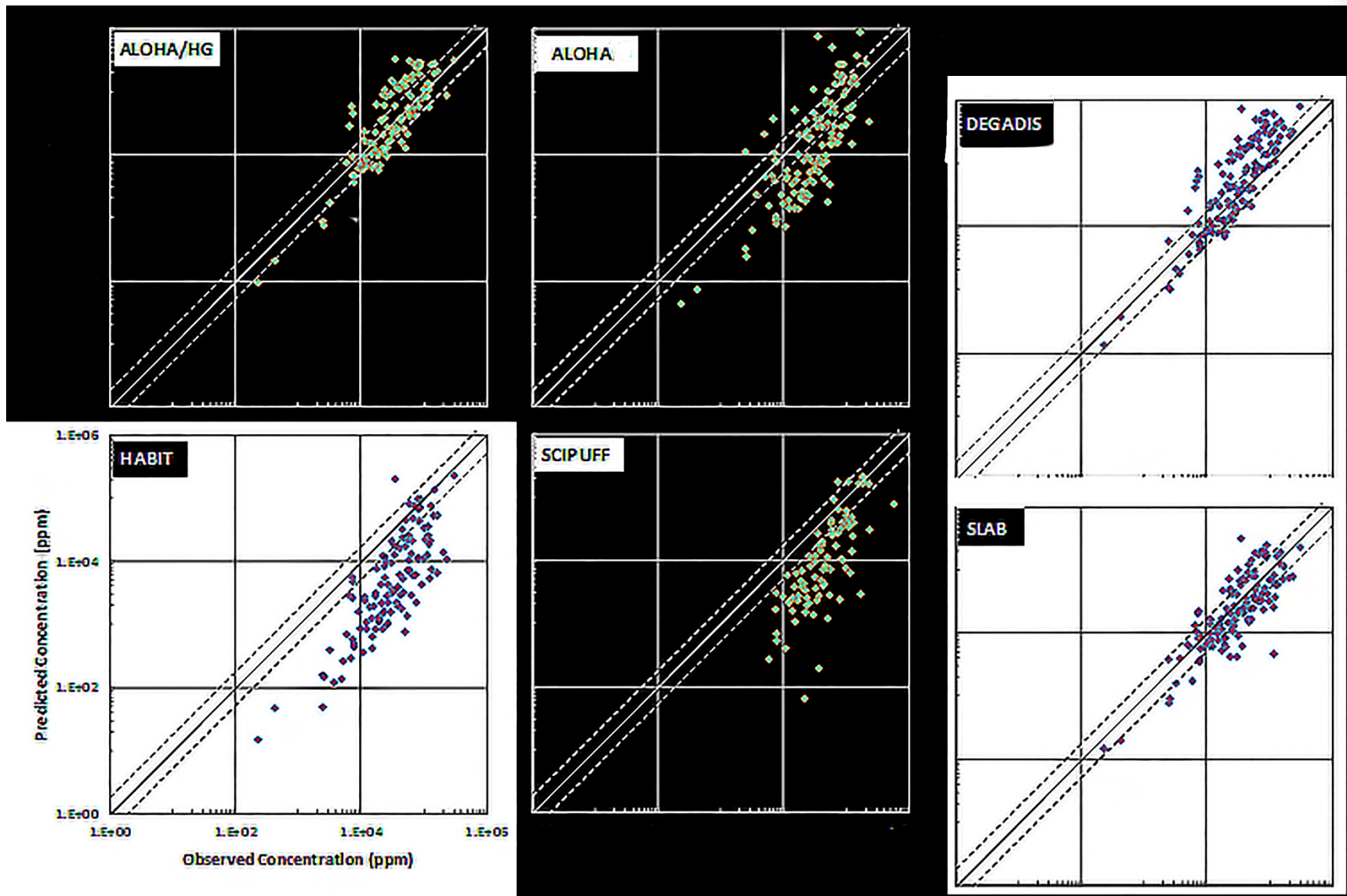


# Experimental Data (Hanna et al.1991)

Parameter	Burro	Coyote	Desert Tortoise	Goldfish	Hanford (continuous)	Hanford (Instantaneous)	Maplin Sands	Prairie Grass	Thorney Island (continuous)	Thorney Is. (instantaneous)
Number of trials	8	3	4	3	5	6	4, 8 <sup>a</sup>	44	2	9
Location	China Lake, Calif.	China Lake, Calif.	Nevada Test Site, Nev.	Nevada Test Site, Nev.	Richland, Wash.	Richland, Wash.	Maplin Sands, U.K.	Near O'Neill, Neb.	Thorney Island, U.K.	Thorney Island, U.K.
Period	Jun.-Sep. 1980	Sep.-Oct. 1981	Aug.-Sep. 1983	Aug. 1986	Sep.-Nov. 1967	Sep.-Nov. 1967	Sep. 1980, Sep.-Oct. 1980	Jul.-Aug. 1956	Jun. 1984	Aug. 1982-Jun. 1983
Material	LNG	LNG	NH <sub>3</sub>	HF	Krypton-85	Krypton-85	LNG, LPG	SO <sub>2</sub>	Freon-12, N <sub>2</sub>	Freon-12, N <sub>2</sub>
Type of release	Boiling liquid (dense gas)	Boiling liquid (dense gas)	2-phase jet (dense gas)	2-phase jet (dense gas)	Gas (non-buoyant)	Gas (non-buoyant)	Boiling liquid (dense gas)	Gas jet (non-buoyant)	Gas (dense gas)	Gas (dense gas)
Total mass (kg)	10,700-17,300	6,500-12,700	10,000 - 36,800	3,500-3,800	11-24 <sup>b</sup>	10 <sup>b</sup>	2,000-6,600, 1,500-8,400	23-63	4,800	3,150-8,700
Release duration (s)	79-190	65-98	126-381	125-360	598-1,191	(instantaneous)	100-230, 90-360	600	460	(instantaneous)
Surface	Water	Water	Soil	Soil	Soil	Soil	Water	Soil	Soil	Soil
Surface roughness (m)	0.0002	0.0002	0.003	0.003	0.03	0.03	0.0003	0.006	0.01	0.005-0.018
P-G stability class	C-E	C-D	D-E	D	C-F	C-F	D, C-D	A-F	E-F	D-F
Max. distance (m)	140-800	300-400	800	1,000-3,000	800	800	180-650, 250-650	800	472	410-580
Min. averaging time (s)	1	1	1	66.6-88.3	38.4	4.8	3	(dosage)	30	0.6
Max. averaging time (s)	40-140	50-90	80-300	66.6-88.3	269-845	4.8	3	600	30	0.6

<sup>a</sup> The first and second values denote LNG and LPG, respectively, if any.

<sup>b</sup> Curies, rather than kg, are used as a measure of the amount of this radioactive tracer released.



**Comparison between the “Observed”  
and “Predicted” Concentrations (ppm)**

# Modules Selected

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- **DEGADIS (Thomas Spicer)** solves the gas concentrations by gravity-driven, over flat terrain, then into the entrainment layers.
- **SLAB (Donald Ermak)** solves gas concentrations by mass, energy, and momentum balances at downwind locations.

**Both Models can perform for release from:  
pool evaporation, jets, and explosion scenarios.**



# HABIT Phase-II

## Milestone & Schedule

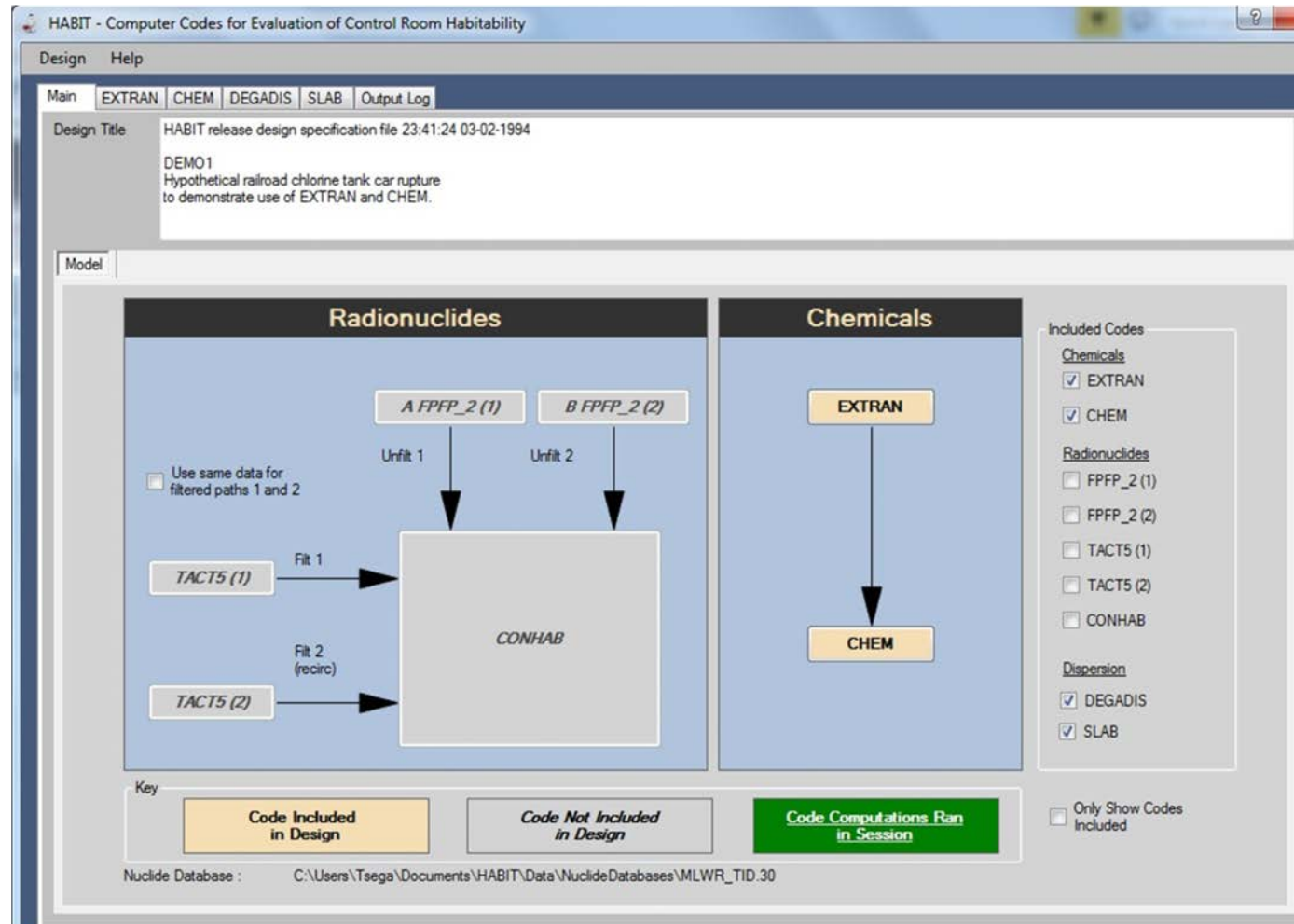
**Program Schedule: April 20, 2015 – April 04, 2016**

**Kickoff: April 20, 2015**

Task	Main Objective	Duration (days)	Finish Date
1	Re-host D&S	109	June 22
2	Integrate D&S	113	Oct. 16
3	V&V HABIT v 2.0	73	Jan. 26, 16
4	Update NUREG/CR-6210	85	April 4, 16

**D&S: DEGADIS and SLAB**

# HABIT v2.0 Main Screen



# DEGADIS' 4 Modules

**GTI-04/0049 - DEGADIS 2.1:  
Dense Gas Dispersion Model for  
LNG...**

**DEGADIS 2.1: Dense Gas Dispersion Model  
for LNG Vapor Dispersion**

Federal regulations governing LNG dispersion protection (49 CFR 193.2059) specify DEGADIS as an acceptable means of determining flammable vapor-gas dispersion distances.

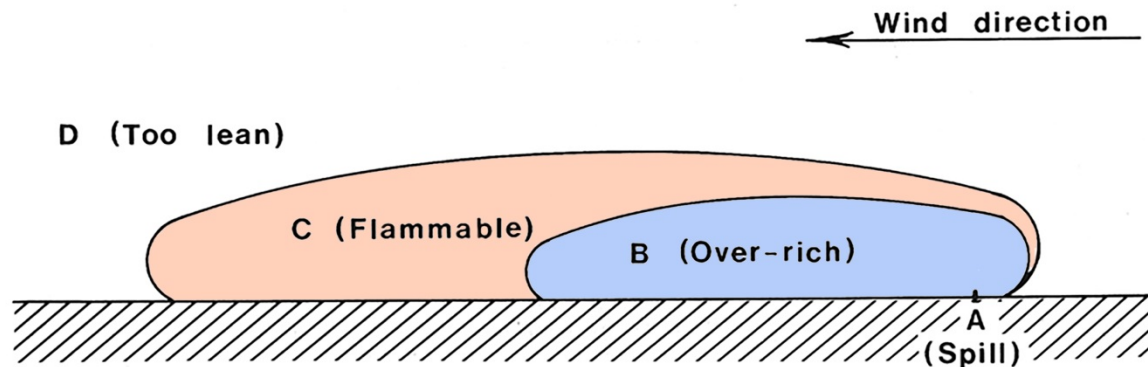
**\$500.00**

1

Add to Cart

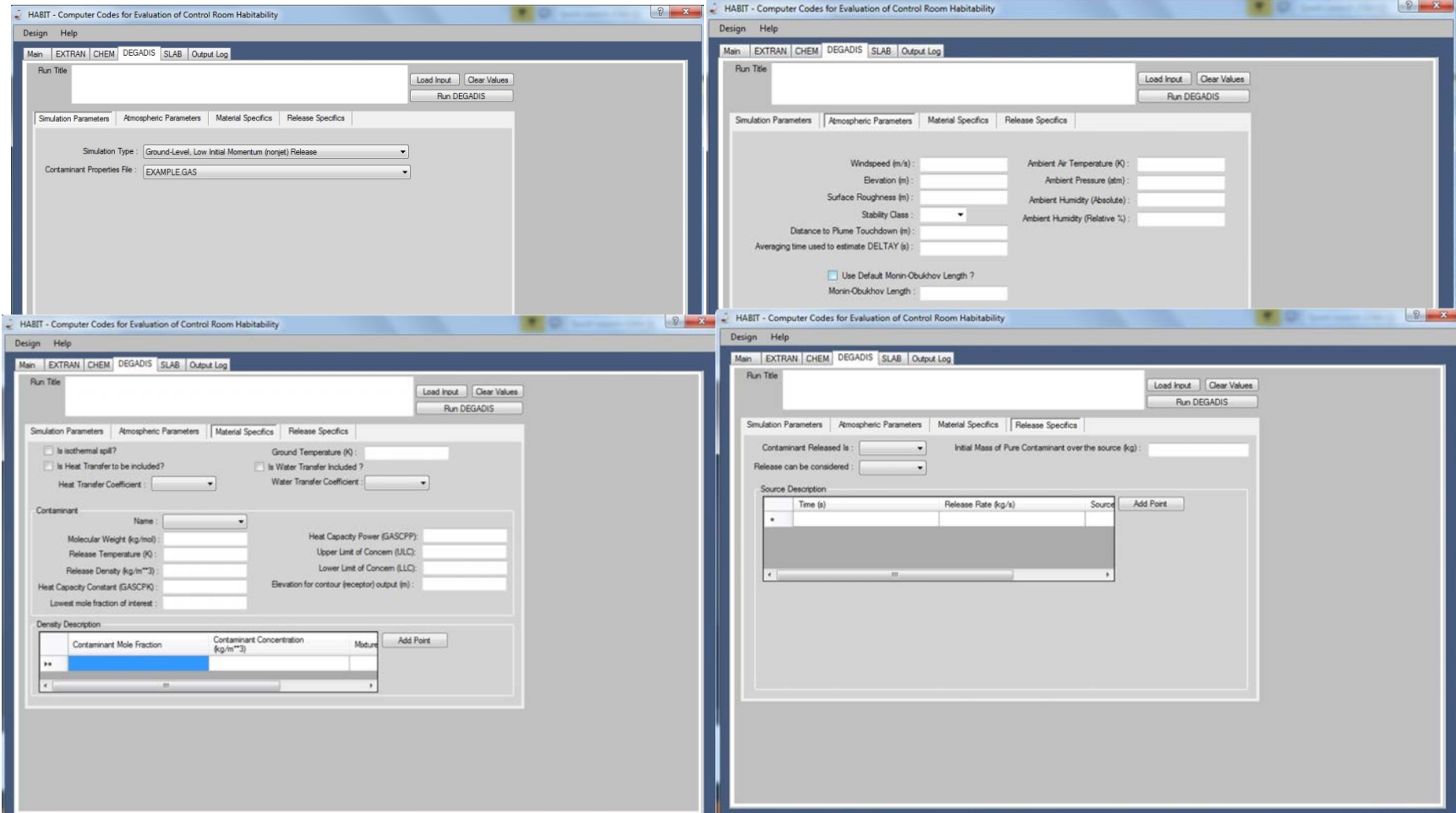
Availability: In Stock

- Simulation Processes
- Atmospheric Processes
- Chemical Specifications
- Release Specifications





# DEDAGIS: GUI



The image displays four screenshots of the HABIT - Computer Codes for Evaluation of Control Room Habitability GUI, showing different tabs and input fields.

**Top Left Screenshot (Main Tab):**

- Run Title: [Empty]
- Buttons: Load Input, Clear Values, Run DEGAIS
- Simulation Parameters: Ground-Level, Low Initial Momentum (nonjet) Release
- Contaminant Properties File: EXAMPLE.GAS

**Top Right Screenshot (EXTRAN Tab):**

- Run Title: [Empty]
- Buttons: Load Input, Clear Values, Run DEGAIS
- Simulation Parameters: Atmospheric Parameters
- Windspeed (m/s): [Empty]
- Elevation (m): [Empty]
- Surface Roughness (m): [Empty]
- Stability Class: [Empty]
- Distance to Plume Touchdown (m): [Empty]
- Averaging time used to estimate DELTAY (s): [Empty]
- Use Default Morin-Obukhov Length? [Empty]
- Morin-Obukhov Length: [Empty]
- Ambient Air Temperature (K): [Empty]
- Ambient Pressure (atm): [Empty]
- Ambient Humidity (Absolute): [Empty]
- Ambient Humidity (Relative %): [Empty]

**Bottom Left Screenshot (CHEM Tab):**

- Run Title: [Empty]
- Buttons: Load Input, Clear Values, Run DEGAIS
- Simulation Parameters: Material Specifics
- Is isothermal spill? [Empty]
- Is Heat Transfer to be included? [Empty]
- Heat Transfer Coefficient: [Empty]
- Ground Temperature (K): [Empty]
- Is Water Transfer Included? [Empty]
- Water Transfer Coefficient: [Empty]
- Contaminant Name: [Empty]
- Molecular Weight (kg/mol): [Empty]
- Release Temperature (K): [Empty]
- Release Density (kg/m<sup>3</sup>): [Empty]
- Heat Capacity Constant (GASCPK): [Empty]
- Lowest mole fraction of interest: [Empty]
- Heat Capacity Power (GASCPK): [Empty]
- Upper Limit of Concern (ULC): [Empty]
- Lower Limit of Concern (LLC): [Empty]
- Elevation for contour (receptor) output (m): [Empty]
- Density Description: Contaminant Mole Fraction, Contaminant Concentration (kg/m<sup>3</sup>), Mixture

**Bottom Right Screenshot (DEGAIS Tab):**

- Run Title: [Empty]
- Buttons: Load Input, Clear Values, Run DEGAIS
- Simulation Parameters: Release Specifics
- Contaminant Released is: [Empty]
- Initial Mass of Pure Contaminant over the source (kg): [Empty]
- Release can be considered: [Empty]
- Source Description: Time (s), Release Rate (kg/s), Source, Add Point

# SLAB (1-1)

HABIT - Computer Codes for Evaluation of Control Room Habitability

Design Help

Main EXTRAN CHEM DEGADIS **SLAB** Output Log

Run Title

Source Type and Numerical Step Parameters

Spill Source Type :   
Numerical Substep :

Source Properties

Molecular Weight of source material (kg) :   
Vapor heat capacity at constant pressure (J/kg-K) :   
Boiling Point Temperature (K) :   
Initial Liquid Mass Fraction :   
Heat of vaporization (J/kg) :   
Liquid heat capacity (J/kg-K) :   
Liquid density of source material (kg/m<sup>3</sup>) :   
Saturation pressure constant (SPB) :   
Saturation pressure constant (SPC) :

Spill Parameters

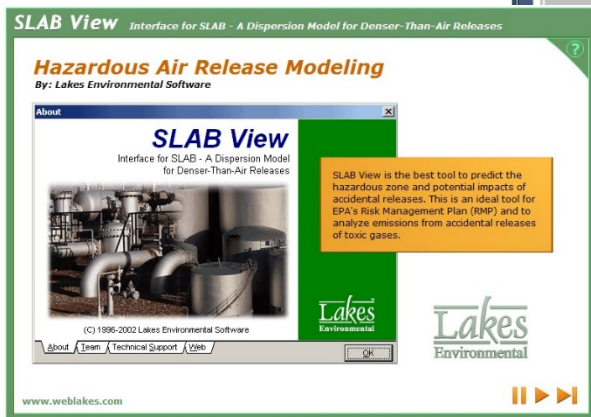
Temperature of source material (K) :   
Mass source rate (kg/s) :   
Source area (m<sup>2</sup>) :   
Continuous source duration (s) :   
Instantaneous source mass (kg) :   
Source height (m) :

Field Parameters

Concentration averaging time (s) :   
Maximum downwind distance (m) :   
Heights of concentration calculation (m) :

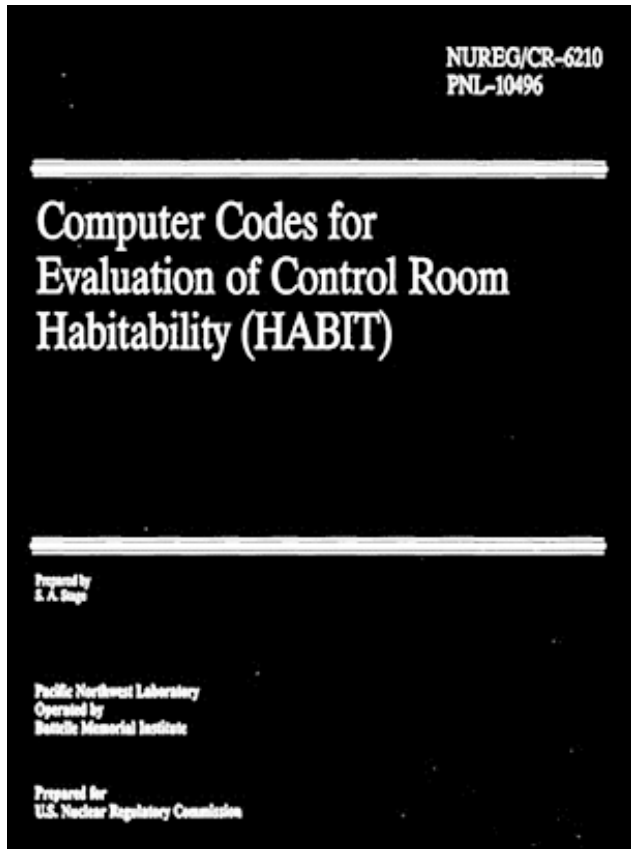
Meteorological Parameters

Surface roughness height (m) :   
Ambient measurement height (m) :   
Ambient wind speed (m/s) :   
Ambient Temperature (K) :   
Relative humidity (%) :   
Stability Class :   
Inverse Monin-Obukhov length (1/m) :



# Work-in-Progress

- Analyze and integrate D&S
- V&V HABIT v2.0 I/O data
- Update TBDs



**Targeted completion date: 9/30/2016**



# On-Going Enhancements



- Adding chemicals
- Adding graphic analysis
- Adding ICRP 60/103 dose coefficients
- Supporting RAMP
- Benchmark ATD Models

# The 6 have 7 Brains







## Protecting People and the Environment



***Casper.Sun@NRC.Gov***