General Characteristics		
1	**Abstract of Model Capabilities**	The HOTMAC/RAPTAD modeling system is particularly useful for prediction of transport and diffusion processes over complex terrain where conventional methods fail. Applications of model include: emergency-response management associated with accidental release of toxic materials, environmental assessment for city and industrial site planning, decision-making in weather-influenced field operations, and atmospheric boundary-layer research.
2	**Sponsor and/or Developing Organization**	Los Alamos National Laboratory P.O. Box 1663 Los Alamos, NM 87544
3	**Last Custodian/ Point of Contact**	YSA Corporation Rt. 4 Box 81-A Santa Fe, NM (505) 989-7351 (505) 989-7965 **Fax** ysa@ysasoft.com **primary individual**
4	**Life-Cycle**	The models were originally developed as research tools by using a super computer. In the mid 1980's, the models were ported to desktop computers as engineering workstations advanced their capabilities. Currently the models are also running on PCs. In 1989, YSA obtained an exclusive license from Los Alamos National Laboratory for commercialization of the software. YSA improved model physics, added high-quality graphics, and developed a comprehensive graphical user interface.
5	**Model Description Summary**	YSA corporation offers a comprehensive modeling system for environmental stddies. The system includes a mesoscale meteorological code, a transport and diffusion code, and extensive Graphical User Interfaces (GUIs). This system is unique because the diffusion code uses time dependent, three-dimensional winds and turbulence distributions that are forecasted by a mesoscale weather prediction model. Consequently the predicted concentration distributions are more accurate than those predicted by traditional models when surface conditions are heterogeneous. In general, the modeled concentration distributions are not Gaussian because winds and turbulence distributions change considerably in time and space over complex terrain. HOTMAC has options to include non-hydrostatic pressure computation, nested grids, land-use distributions and precipitation physics. HOTMAC can interface with tower, rawinsonde, and large-scale weather data using a four-dimensional data assimilation method. RAPTAC, Random Puff Transport and Diffusion, is a Lagrangian random puff model that is used to forecast transport and diffusion of airborne materials over complex terrain. Concentrations are computed by summing the concentration of each puff at the receptor location. The random puff method is equivalent to the random particle method with a Gaussian kernel for particle distribution. The advantage of the puff method is the accuracy and speed of computation. The particle method requires the release of a large number of particles which could be computationally expensive. The puff method requires the release of a much less number of puffs, typically 1/10 to 1/100 of the number of particles required by the particle method.
6	**Application Limitation**	Model applications are limited to basic transport and diffusion of neutral, buoyant and dense gas plumes. Some chemical applications are possible by adopting appropriate source models as preprocessor.
7	**Strengths/ Limitations**	**Strengths:** The model has true forecast capabilities in three-dimensional space over complex terrain. Model equations are based on the fundamental laws of physics such as conservation equations of momentum, internal energy and mass. **Limitations:** Computations relatively take a long time, which is subject to the grid spacing, number of grid points and the computer used.
8	**Model References**	• "A Hierarchy of Turbulence-Closure Models for Planetary Boundary Layers," Mellor, G.L., and T. Yamada, *Journal of Atmospheric Sciences*, 31, 1791-1806 (1974). • "Development of a Turbulence Closure Model for Geophysical Fluid Problems," Mellor, G.L. and T. Yamada, *Rev. Geophys. Space Phys.,* 20, 851-875 (1982). • "Development of a Nested Grid, Second Moment Turbulence Closure Model and Application to the 1982 ASCOT Brush Creek Data Simulation," Yamada, T., and S. Bunker, *Journal of Applied Meteorology*, 27, 562-578 (1988). • "A Numerical simulation of Airflows and SO_2 concentration Distributions in an Arid South-Western Valley," Yamada, T., *Journal of Atmospheric Environment,* 26A, 1771-1781 (1992). • "A Numerical Simulation of Atmospheric Transport and Diffusion over Coastal Complex Terrain," Yamada, T., S., Bunker, and M. Moss, *Journal of Applied Meteorology,* 31, 565-578 (1992).

9	**Input Data/Parameter Requirements**	HOTMAC requires meteorological data for initialization and to provide boundary conditions if the boundary conditions change significantly with time. The minimum amount of data required to run HOTMAC is wind and potential temperature profiles as a single station. HOTMAC forecasts wind and turbulence distributions in the boundary layer through a set of model equations for solar radiation, heat energy balance at the ground, conservation of momentum, conservation of internal energy, and conservation of mass. Terrain Data: HOTMAC and RAPTAD use the digitized terrain data from the U.S. Geological Survey and the Defense Mappping Agency. Extraction of terrain data is greatly simplified by using YSA's GUI software called Topo. The user specifies the latitudes and longitudes of the southwest and northeast corner points of the study area. Then, Topo extracts the digitized elevation data within the area specified and converts from the latitudes and longitudes to the UTM (Universal Transverse Mercator) coordinates for up to three nested grids. Emission Data: Emission data requirements are emission rate, stack height, stack diameter, stack location, stack gas exit velocity, and stack buoyancy. Receptor Data: Receptor data requirements are names, location coordinates, and desired averaging time for concentration estimates, which is variably from 5 to 15 minutes.
10	**Output Summary**	HOTMAC outputs include hourly winds, temperatures, and turbulence variables at every grid point. Ancillary codes graphically display vertical profiles of wind, temperature, and turbulence variables at selected locations and wind vector distributions at specified heights above the ground. These codes also produce graphic files of wind direction projected on vertical cross sections. RAPTAD outputs include hourly values of surface concentration, time variations of mean and standard deviation of concentrations at selected locations, and coordinates of puff center locations. Ancillary codes produce color countour plots of surface concentration, time variations of mean concentrations and ratios of standard deviation to mean value at selected locations, and concentration distributions of the vertical cross sections. The averaging time of concentration at a receptor location is variable from 5 to 15 minutes. Color contour plots of surface concentration can be animated on the monitor to review time variations of high concentration areas.
11	**Applications**	• Yamada, T.S. Bunker and M. Moss, 1992. A Numerical Simulation of Atmospheric Transport and Diffusion over Coastal Complex Terrain. *Journal of Applied Meteorology,* 31: 565-578. • Yamada, T. and T. Henmi, 1994. HOTMAC: Model Performance Evaluation by Using Project WIND Phase I and II Data. *Mesoscale Modeling of the Atmosphere, American Meteorological Society,* Monograph 47, pp. 123-135.
12	**User-Friendliness**	Comprehensive graphical user interfaces are available for all model operations: execution of preprocessors, setting input parameters, running HOTMAC and RAPTAD, running graphical programs, and displaying the graphics.
13	**Hardware-Software Interface Constraints/ Requirements**	**Computer operating system:** UNIX **Computer platform:** Supercomputer, workstation, PC **Disk space requirements:**1-10 GByte **Run execution time** (for a typical problem)**:** HOTMAC 2-8 hours for a 24 hour simulation; RAPTAD 20 seconds for 1 hour simulation. **Programming language:** Fortran, C **Other computer peripheral information:** NCAR graphics
14	**Operational Parameters**	**Identify whether the code has any error diagnostic messages to assist the user in troubleshooting operational problems:** **Set up time for: Typical times are:** ***first-time user:*** ***experienced user:*** 1 day
16	**Runtime Characteristics**	HOTMAC and RAPTAD have been running on workstations and PCs with UNIX operation system. HOTMAC: 2-8 hours for a 24 hour simulation. RAPTAD: 20 seconds for a 1-hour simulation.

Specific Characteristics		
Part A: Source Term Submodel Type (Not Applicable)		
Part B: Dispersion Submodel Type		
B2	**Similarity**	**__ Plume** **✔ Puff**
B3	**Stochastic**	**__ Monte Carlo** **✔ Random walk**
B7	**Turbulent Kinetic Energy (TKE)-Driven**	Random walk and puff concentration standard deviations are computed by turbulence predicted by HOTMAC.
B9	**Multiple Capabilities**	Combination of random walk and puff.

Part C: Transport Submodel Type		
C1	**Prognostic**	Puffs are transported by the mean and turbulence winds, which are forecasted by a three-dimensional mesoscale model, HOTMAC.
C2	**Deterministic**	At each time step new locations of puffs are computed deterministically from the current positions.
C3	**Stochastic**	Turbulence winds are computed stochastically with a random number generator and standard deviations of winds predicted by HOTMAC.
C4	**Frame of Reference**	**__ Eulerian ✔ Lagrangian __ Hybrid __ Eulerian-Lagrangian**
Part D: Fire Submodel Type (Not Applicable)		
Part E: Energetic Events Submodel Type (Not Applicable)		
Part F: Health Consequence Submodel Type (No Information Provided.)		
Part G: Effects and Countermeasures Submodel Type (No Information Provided.)		
Part H: Physical Features of Model		
H2	**Release Elevation**	**✔ ground ✔ roof**
H6	**Mixing Layer**	**✔ trapping ✔ lofting __ reflection ✔ penetration** **✔ inversion breakup fumigation ✔ temporal variability**
H7	**Cloud Buoyancy**	**✔ neutral [passive] ✔ dense [negative] ✔ plume rise [positive]**
H13	**Temporally and Spatially Variant Mesoscale Processes**	**Urban heat island:** Provided by HOTMAC **Canopies:** Provided by HOTMAC **Complex terrain (land) effects: ✔ mountain-valley wind reversals** **✔ anabatic winds ✔ katabaic winds** **Complex terrain (land-water) effects: ✔ seabreeze airflow trajectory reversals** **✔ Thermally Induced Boundary Layer definition ✔ seabreeze fumigation** **✔ landbreeze fumigation** **Thunderstorm outflow:** Provided by HOTMAC **Temporally variant winds:** Provided by HOTMAC **High velocity wind phenomena: __ tornado ✔ hurricane __ supercane __ microburst**
Part I: Model Input Requirements		
I1	**Radio(chemical) and Weapon Release Parameters**	**Release rate: ✔ Continuous ✔ Time dependent ✔ Instantaneous** **Release container characteristics: __ vapor temperature __ tank diameter** **__ tank height ✔ tank temperature __ tank pressure __ nozzle diameter** **__ pipe length** **Jet release: __ initial size __ shape** **__ concentration profile at end of jet affected zone** **Release dimensions: ✔ point ✔ line ✔ area** **Release elevation: ✔ ground ✔ roof ✔ stack**
I2	**Meteorological Parameters**	**Wind speed and wind direction: __single point __ single tower/multiple point** **✔ multiple towers** **Temperature: __ single point __ single tower/multiple point ✔ multiple towers** See above. **Dew point temperature: __ single point __ single tower/multiple point** **✔ multiple towers** **Precipitation: __ single point __ single tower/multiple point ✔ multiple towers** **Turbulence typing parameters: __ temperature difference __ sigma theta** **__ sigma phi __ Monin-Obukhov length __ roughness length** **__ cloud cover __ incoming solar radiation __ user-specified** **Four dimensional meteorological fields from prognostic model:** HOTMAC provides 3-D distributions of mean and turbulence variables.
Part J: Model Output Capabilities		
J2	**Graphic Contours and Resolution**	Concentration contours on the surface and vertical cross sections.
J3	**Concentration Versus Time Plots**	Mean and standard deviation of concentration versus time.

Part K: Model Usage Considerations		
K1	**Ease of Model Use**	**Training required to run the model: __ background (years of education)** **_✔_ training time needed on the model to be able to exercise all model capabilities** 2 days **Training required to continue development of the model:** **__ background (years of education)** **__ training time needed on the model to be able to exercise all model capabilities**
K2	**Time to Process From Notification of Release (including data acquisition) to Production of Product Listed in #K1, Listed for Platforms for Which the Program is Already Compiled**	Approximately 20 seconds for a one hour prediction.
K3	**Ease of Use of Output, Evaluated as the Time Needed to Train a College Graduate in the Use of the Output**	2 days