	General Characteristics	
1	**Abstract of Model Capabilities**	The Chemical Accident Stochastic Risk Assessment Model (CASRAM) is used in the statistical analysis of consequence and risk from accidents associated with hazardous materials transportation or industrial plant/facility use (e.g., processing, handling, and storage). The CASRAM modeling concept involves two primary components. The first is a meteorological prepocessor, which uses routine National Weather Service observation or similar data to determine hourly values of key atmospheric turbulence parameters. The second component uses the meteorological information together with transportation or storage attributes to analyze thousands of individual potential accidents through statistical sampling of accident scenario parameters. A post processor to the model is used for the statistical analysis of model results providing the distribution of hazard zone size and/or exposed population. The model also exists in a single-case (i.e., deterministic) version that is denoted as CASRAM-SC.
2	**Sponsor and/or Developing Organization**	Argonne National Laboratory (ANL)/University of Illinois (U of I) Sponsors: Department of Transportation, Research and Special Programs Administration/Department of Energy, Office of Environmental Management. ANL: 630-252-3447 630-252-3194 **FAX** U of I: 217-333-3832 217-244-4416 **FAX**
3	**Last Custodian/ Point of Contact**	Michael Lazaro, David F. Brown, William E. Dunn (217) 333-9054 (217) 244-4416 **Fax**
4	**Life-Cycle**	CASRAM has been under development since 1993 under sponsorship from the Department of Transportation and the Department of Energy. The preliminary model components consisting of a meteorological preprocessor for the analysis of National Weather Service observations and a simple dispersion model were originally developed in 1993. The source model was added in 1994. All components of the model (meteorolgical preprocessor, source model and dispersion model) were upgraded in 1996 and 1997.
5	**Model Description Summary**	The source component of CASRAM determines chemical release rates for specified chemical spill and/or vaporization scenarios. Several types of release estimates can be provided; including quasi-instataneous release scenarios and estimating release rates, the source model in CASRAM accesses a database of the key physical properties for over 200 chemical compounds. Discharge fraction and emission rate estimates are for near-surface and surface releases. The current version of CASRAM contains statistical empirically based upon data contained in the Hazardous Materials Incident Reporting System (HMIRS) maintained by the U.S. Department of Transportation. Discharge fractions can also be the U.S. Department of Transportation. Discharge fractions can also be directly (specified release quantity) or indirectly (e.g., specified chemical amount (s) and state properties and container size and rupture location) controlled or specified by the user. Pool chemical evaporation within CASRAM is determined using a time-dependent energy-budget model that carefully accounts for the key air-pool-ground energy fluxes that govern the evaporation rate. Heat transfer to and from the pool is treated via explicit consideration of solar radiation, air convection, ground conduction, and evaporative heat loss from the pool. Transport and dispersion within CASRAM is simulated using a continous plume model for releases from evaporating pools and a single-puff model for short-duration, quasi-instantaneous releases. Vertical turbulent diffusion is treated using a Lagrangian integral dispersion model that is parameterized in terms of atmospheric boundary layer simarity parameters. Horizontal turbulent diffusion is represented with Gaussian relationships that are parameterized in terms of the Lagrangian time scale and lateral wind direction fluctuations. CASRAM is capable of estimating hazard zones or hazard population exposure for single and multiple chemical releases. Health effect threshold concentrations, required for determining hazard-zone estimates, are specified as model input parameters allowing simple adjustment for modeling varying health impacts. When a multiple chemcial release is considered, the combined toxicological effects are treated as outlined in the American Congress of Government and Industrial Hygienists Threshold Limit Value documentation.
6	**Application Limitation**	CASRAM currently does not treat plume buoyancy (e.g., dense gas effects and plume rise) and is not application for near surface releases ($z > 20m$ or so). Complex-terrain effects are not considered. Even though multiple chemical are treated in terms of toxicological effects, chemical interaction of mixtures and chemical transformation is not currently addressed in CASRAM.

7	**Strengths/ Limitations**	**Strengths:** 1) Statistical treatment of potential hazardous material accidents both in terms of source strength and meteorology. 2) State-of-art treatment of meteorology and dispersion for individual accidents scenarios. 3) Model is designed to interface with standard routing codes allowing convenient risk analysis of hazardous material transportation risk including estimation of exposed population. **Limitations:** 1) Model does not treat dense gas releases 2) Model does not treat elevated releases 3) Complex terrain effects are not considered. The most problematic of these weaknesses is the absence of a dense-gas submodel. The model developers intend to incorporate a dense-gas model within the near future. The later two weaknesses of limitations only apply to fixed facility analyses.
8	**Model References**	! Brown, D.F., W.E. Dunn, M. Lazaro (1997) CASRAM: *The Chemical Accident Stochastic Risk Assessment Model: Technical Documentation - Beta Version 0.7.* Argonne National Laboratory, Argonne IL. ! Brown, D.F., W. E. Dunn, M. Lazaro (1997) *Users Guide for CASRAM-SC* Argonne, National Laboratory, Argonne IL. ! Brown, D.F., W.E. Dunn and A.J. Policastro (1996) "Application of CASRAM to Assess Risk in Transportation Risk Assessment", proceedings of the U.S. Army Forces Command Real World Air Conference held in Colorado Springs, CO, Sept. 3-5, 1996. ! Lazaro, M.A. etal (1996), Risk Assessment for the Transportation of Hazardous Waste and Hazardous Waste Components of the Low-Level Mixed Waste and Transuranic Waste for the U.S. Department of Energy Waste and Management Programmatic Environmental Impact Statement, ANL/EAD/TM-28, December. ! Hartmann, H.M., A.J. Policastro, and M.A. Lazaro (1994), Hazardous Waste Transportation Risk Assessment for the U.S. Department of Energy Environmental Restoration and Waste Management Program - Human Health Endpoints, Vol. 2, published in the proceedings of the WM'95 Conference, Tucson, AR, February 26 - March 2, 1995. ! W.E. Dunn, Brown, D.F. and A.J. Policastro (1996) Technical Documentation in Support of the 1996 Emergency Response Guidebook, NTIS UILU-ENG-97-4001, prepared for the U.S. Department of Transportation, Office of Hazardous Materials Technology, University of Illinois, Urbana, IL.
9	**Input Data/Parameter Requirements**	For use with transportation-related analyses, CASRAM interfaces with the standard route-generating codes HIGHWAY 3.3 and INTERLINE 5.0. These codes provide a sequence of discrete route segments with associated latitude, longitude and population density information. Therefore, the user need only supply the origination and destination for the shipments. Shipment size and one concentration threshold, corresponding to different averaging times, are accepted. Alternatively, the model will also accept a probit value for the chemical (s) analyzed. For a fixed-site analysis, the chemical (s) involved, the location, and the concentration thresholds are required for the particular process or storage scenario considered, since the discharge-fraction distributions available with CASRAM are only for transportation-related releases. The available discharge fractions do include those for loading and loading or transportation shipments, however. (Fixed site discharge-fraction distributions process and storage are currently under development.) Meteorological data necessary for CASRAM are obtained from NWS surface and upper air stations. The meteorological data are processed using a meteorological prepocessed meteorological database. This database currently includes data from 64 cities in the United States from 1985-1989. Chemical data required for the source model are contained in a separate file and are keyed by CAS number. The chemical databases currently contains data for approximately 200 chemicals. For chemicals not currently in the database, molecular weight, critical temperature, critical volume, boiling point, liquid density, vapor pressure and heat of vaporization are required. Temperature dependent property data are accepted and employed where applicable.
10	**Output Summary**	The output of CASRAM consists of a predetermined number of estimates (user specified) of hazard-zone size and, if applicable, exposed populations. A post processor to the model analyzes these intermediate data to provide the probability distributions of hazard-zone size and/or exposed population. Through use of the post processor, several separate transportation shipments can be considered and, if desired, separately weighted in the same consequence distribution.
11	**Applications**	CASRAM has been used in the preparation of the Department of Transportation Emergency Response Guidebook, the Department of Energy Hazardous Waste Management Programatic EIS, as well as several smaller risk assessment studies for the Department of Energy and Department of Defense.
12	**User-Friendliness**	At the current time, CASRAM does not have a friendly user interface. Users must set up problems in a command-line text file and must be run under a UNIX or DOS environment.

13	**Hardware-Software Interface Constraints/ Requirements**	**Computer operating system:** Unix or DOS **Computer platform:** 486 or Pentium class PC or Sun 4 or higher workstation **Disk space requirements:** About 250 MB of hard-disk space is necessary for meteorological database and intermediate analysis files. **Run execution time** (for a typical problem)**:** 2-12 hours on a Sun 5 workstation **Programming language:** FORTRAN-77 **Other computer peripheral information:**
14	**Operational Parameters**	**Identify whether the code has any error diagnostic messages to assist the user in troubleshooting operational problems:** Several error messages are displayed in the event of unreadable or nonsensical input data guiding the user to the source of the problem. **Set up time for: Typical times are: *first-time user:*** 2-4 days ***experienced user:*** 1-2 hours
15	**Surety Considerations**	**All quality assurance documentation:** **Benchmark runs:** **Validation calculations:** **Verification with field experiments that has been performed with respect to this code:** Pool evaporation calculations have been checked against published data for hydrocarbon evaporation. Dispersion estimates have been validated with numerous field and laboratory data including Project Prairie Grass.
16	**Runtime Characteristics**	Run times vary from 2-12 hours on a Sun 5 workstation for the statistical analysis of 100,000 accidents. CASRAM has not been run on a PC workstation to this date. It is expected that on a PC-class machine, execution times would be somewhat longer.

Specific Characteristics

Part A: Source Term Submodel Type

A1	**Source Term Algorithm?**	_✔_YES __NO
A2	**For Chemical Consequence Assessment Models**	**Liquid spill: _✔_ pool evaporation _✔_ particulate resuspension** Pool chemical evaporation within CASRAM is determined using a time-dependent energy-budget model that carefully accounts for the key air-pool-ground energy fluxes that govern the evaporation rate. Heat transfer to and from the pool is treated via explicit consideration of solar radiation, air convection, ground conduction, and evaporative heat loss from the pool. **Pressurized releases:__ two-phase jets _✔_ flashing _✔_ entrainment__ aerosol formation** For liquefied gases, flashing is calculated based on a thermodynamic balance of the chemical involved. Entrainment rates into the flashed material are based on simple empirical relationships. For pressurized gases, standard blowdown relationships are employed. **Solid spills: _ resuspension _✔_ sublimation**
A3	**For Radiological Consequence Assessment Models**	**Gaseous releases: __ noble gases __ iodines __ other non-reactive gases** The CASRAM source model does not currently include radiological-specific algorithms. **Aerosol releases:** The CASRAM source model does not currently include radiological-specific algorithms. **Particulate releases:** The CASRAM source model does not currently include radiological-specific algorithms. **_ Chemistry __ Isotopic exchange __ Physical properties capability** The CASRAM source model does not currently include radiological-specific algorithms.
A4	**For Weapons Consequence Assessment Models**	**Chemical weapon release characteristics:** The CASRAM source model does not currently include chemical-weapons-specific algorithms. **Biological weapon release characteristics:** The CASRAM source model does not currently include biological-weapons-specific algorithms.

Part B: Dispersion Submodel Type

B1	**Gaussian**	**_✔_Straight-line plume _✔_ Segmented plume __ Statistical plume __ Statistical puff** Horizontal turbulent dispersion is represented with Gaussian relationships that are parameterized in terms of the Lagrangian time scale and lateral wind direction fluctuations. Continuous release calculations are straight-line in nature since terrain effects are not considered. Instantaneous releases are treated as puffs.

B2	**Similarity**	**_✔_ Plume _✔_ Puff** Vertical turbulent dispersion is treated with a Lagrangian-integral model parameterized in terms of mean plume height, average advection velocity, and a dimensionless travel time. These parameters are expressed as integral equations written in terms of plume travel time and atmospheric boundary layer parameters. Continuous releases are treated as plumes, and instantaneous releases are treated as puffs.
B3	**Stochastic**	**__ Monte Carlo __ Random walk** Not applicable in CASRAM
B4	**Gradient Transport or K-Theory**	Not applicable in CASRAM
B5	**Particle-In-Cell**	Not applicable in CASRAM
B6	**Box**	Not applicable in CASRAM
B7	**Turbulent Kinetic Energy (TKE)-Driven**	Not applicable in CASRAM
B8	**Particle**	Not applicable in CASRAM
B9	**Multiple Capabilities**	Not applicable in CASRAM
Part C: Transport Submodel Type		
C1	**Prognostic**	Single-point (in time) meteorological data are used in the calculation of ground-level concentrations. However, for travel times over an hour, concentrations are adjusted to account for changing meteorology.
C2	**Deterministic**	Each accident scenario considered in CASRAM is treated using a deterministic dispersion model based on single-point meteorological data.
C3	**Stochastic**	Although each accident scenario is treated in a deterministic manner, the resulting distributions of hazards zone size or exposed population capture the statistical variability since very large numbers of releases are considered.
C4	**Frame of Reference**	**_ Eulerian __ Lagrangian __ Hybrid _✔_ Eulerian-Lagrangian** Ground-level concentrations are parameterized in terms of mean plume height, average advection velocity and a dimensionless travel time. These parameters are expressed as integral equations written in terms of plume time and atmospheric boundary layer parameters.
Part D: Fire Submodel Type (Not Applicable)		
Part E: Energetic Events Submodel Type (Not Applicable)		
Part F: Health Consequence Submodel Type		
F1	**For Chemical Consequence Assessment Models**	**Health effects: _✔_ fatalities _✔_ cancers __ latent cancers _✔_ symptom onset** CAS RAM is best suited for short-term accidental releases with exposure times under an hour. **Health criteria** **_✔_ IDLH _✔_ STEL _✔_ TLV _✔_ TWA** **_✔_ ERPG _✔_ TEEL _✔_ AEGL _✔_ WHO** **Zones with flammable limits: _✔_ UFL _✔_ LFL** Zones with flammable limits can be calculated using appropriate threshold concentrations. **Blast overpressure regions:** Not currently treated in CASRAM **Fire radiant energy zones:** Not currently treated in CASRAM **Risk qualification:** CASRAM provides risk in terms total exposed area (i.e., hazard zone) or number of people exposed to threshold concentration. Since CASRAM is capable of analyzing many (~1,000,000) scenarios, these numbers are provided as probability distributions. **Concentration: __ single value __ time-history _✔_ integrated dose** **Probits:** CASRAM employees probits when available to find the worst-case averaging time for the particular scenario considered. Averaging times considered are 5 min., 15 min. and 60 min.

F2	**For Radiological Consequence Assessment Models**	**Cloudshine: __ finite cloud __ semi-finite cloud __ other** Not currently treated in CASRAM **Groundshine: __ short-term __ long-term** Not currently treated in CASRAM **Inhalation: _✔_ short-term __ long-term** **_✔_ Total effective dose equivalent** **__ Uptake of respirable fraction of particle spectra** CASRAM will consider these effects when appropriate threshold concentrations are specified. **Resuspension: __ short-term __ long-term __ Anspaugh** Not currently treated in CASRAM **Food/Water Ingestion: __ dynamic _ static** Not currently treated in CASRAM **Skin dose: __ absorption _ other** Not currently treated in CASRAM **Dose assessment: __ ICRP-60 criteria __ organs __ pathways** Not currently treated in CASRAM **Health effects: _✔_ early __ latent** CASRAM will consider these effects appropriate threshold concentrations are specified.
F3	**For Weapons Consequence Assessment Models**	**Health effects: _✔_ fatalities _✔_ cancers __ latent cancers _✔_ symptom onset** CASRAM will consider these effects when appropriate threshold concentrations are specified. However, CASRAM does not contain any weapons-specific algorithms. **Health criteria** **_✔_ IDLH _✔_ STEL _✔_ TLV _✔_ TWA** **_✔_ ERPG _✔_ TEEL _✔_ AEGL** Heath criteria is a user supplied parameter, so any of the above values can be used. However, CASRAM does not contain any weapons specific algorithms. **Risk quantification:** CASRAM provides risk in terms total exposed area (i.e., hazard zone) or number of people exposed to threshold concentration. Since CASRAM is capable of analyzing many (~1,000,000) scenarios, these numbers are provided as probability distributions. **Concentration: _✔_ single value __ time-history _✔_ integrated dose** **Probits:**
Part G: Effects and Countermeasures Submodel Type		
G1	**For Chemical Consequence Assessment Models**	**Evacuation:** CASRAM allows an exclusion distance from the source in the calculation of hazard zone size. **Sheltering:** Not currently considered in CASRAM **Interdiction:** Not currently considered in CASRAM **Spray/Foam:** Not currently considered in CASRAM **Victim Treatment/Treatment Measures:** Not currently considered in CASRAM
G2	**Radiological Consequence Assessment Models**	**Land contamination:** Not currently considered in CASRAM **Economic costs: __ decontamination __ interdiction** **__ foodstuff losses __ denial of facility access __ victim treatment** Economic consequences are not directly calcuated in CASRAM. However, economic costs could be calculated from concentration hazard zone or exposed population distributions. **Evacuation:** CASRAM will allow an exclusion distance in the calculation of hazard zone size. **Sheltering:** Not currently considered in CASRAM **Interdiction:** Not currently considered in CASRAM **Decontamination:** Not currently considered in CASRAM
G3	**For Weapons Consequence Assessment Models**	**Land contamination:** Not currently considered in CASRAM **Economic costs:** Economic consequences are not directly calculated in CASRAM. However, economic costs could be calculated from concentration hazard zone or exposed population distributions. **Evacuation:** CASRAM will allow an exclusion distance in the calculated of hazard zone size. **Sheltering:** Not currently considered in CASRAM **Interdiction:** Not currently considered in CASRAM

Part H: Physical Features of Model		
H1	**Stability Classification Turbulence Typing**	**Pasquill-Gilfford-Turner:** Not used in CASRAM **STAR:** Not used in CASRAM **Irwin:** Not currently used in CASRAM, but could be adopted by a particular user in developing a site specific or regional meteorological database for CASRAM. **Sigma theta:** Not currently used in CASRAM, but could be adopted by a particular user in developing a site specific or regional meteorological database for CASRAM. **Richardson number:** Not used in CASRAM **Monin-Obukhov length:** Atmospheric stability is based on Monin-Obukhov lenght, friction velocity and mixing height. **TKE-driven:** Not used in CASRAM **Split sigma:** Not used in CASRAM
H2	**Release Elevation**	**_✔_ ground _✔_ roof** Releases must be within the lower surface layer (i.e., less than the absolute value of the Monin Obukhov Length)
H3	**Aerodynamic Effects from Buildings and Obstacles**	**__ building wake __ cavity __ K-factors __ flow separation** Not currently treated in CASRAM
H4	**Horizontal Plume Meander**	Effect of plume meander is treated in stable conditions through modification of sigma-Y formulas
H5	**Horizontal/Vertical Wind Shear:**	Not currrently in CASRAM
H6	**Mixing Layer**	**_✔_ trapping __ lofting __ reflection __ penetration** **__ inversion breakup fumigation __ temporal variability** In both stable and unstable conditions, vertical dispersion is limited by the mixing height such that the crosswind integrated concentration approaches an asymptotic, well-mixed value as the downwind distance becomes very large.
H7	**Cloud Buoyancy**	**_✔_ neutral [passive] __ dense [negative] __ plume rise [positive]**
H8	**Cloud Liquid Droplet Formation/ Aerosolization**	Not currently in CASRAM
H9	**(Radio)chemical Transformation and In-Cloud Conversion Processes**	Not currently in CASRAM
H10	**Deposition**	**__ gravitational setting __ dry deposition __ precipitation scavenging** **__ resistance theory deposition __ simple deposition velocity __ liquid deposition** **__ plateout and re-evaporation**
H11	**Resuspension**	Deposition is not currently considered in CASRAM
H12	**Radionuclide Ingrowth and Decay**	Not currently in CASRAM

H13	**Temporally and Spatially Variant Mesoscale Processes**	**Urban heat island:** Urban effects on the surface energy budget are considered in the calculation of atmospheric of atmospheric stability parameters. **Canopies:** Vegetation type and density is used in the calculation of atmospheric stability parameters. **Complex terrain (land) effects: __ mountain-valley wind reversals** **__ anabatic winds __ katabaic winds** Not currently considered in CASRAM **Complex terrain (land-water) effects: __ seabreeze airflow trajectory reversals** **__ Thermally Induced Boundary Layer definition __ seabreeze fumigation** **__ landbreeze fumigation** Not currently considered in CASRAM **Thunderstorm outflow:** Not currently considered in CASRAM **Temporally variant winds:** Not currently considered in CASRAM **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** Instantaneous and time dependent release rate is calculated internally for each accident scenario modeled in the statistical analysis. **Release container characteristics:** __ **vapor temperature** _✔_ **tank diameter** _✔_ **tank height** __ **tank temperature** __ **tank pressure** __ **nozzle diameter** __ **pipe length** For transportation accidents, the user must provide container type, container capacity, and how many are being transported. Temperature and pressure information for storage and transportation vessels is calculated internally from meteorological data in the statistical analysis. **Jet release:** __ **initial size** __ **shape** __ **concentration profile at end of jet affected zone** **Release dimensions:** _✔_ **point** _ **line** _✔_ **area** Discharges from pressurized vessels are treated as point sources, and releases from evaporating pools are treated as area sources. Pool size is calculated internally for each accident scenario modeled in the statistical analysis. **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** **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:**
Part J: Model Output Capabilities (See Item 10.)		
Part K: Model Usage Considerations (No Information Provided.)		