DEFENSE THREAT REDUCTION AGENCY

NUCLEAR TEST PERSONNEL REVIEW PROGRAM

RADIATION DOSE ASSESSMENT

STANDARD OPERATING PROCEDURE

RA01 – Radiation Dose Assessment for Cases Requiring Detailed Analysis

Revision 2.0

Cleared for Release

Key to SOP ID Codes

RA (Radiation Assessment - SOP)
ED (External Dose - Standard Methods)
ID (Internal Dose - Standard Methods)
UA (Uncertainty Analysis - Standard Methods)

Revision Control			
Revision	Revision Description	Revision Date	Authorization Official
1.0	Original	10/31/2007	Paul K. Blake
1.1	- Section 5: Added references to SOP RA04 for preparing RDA reports and calculation worksheets. References to Attachments 2 and 3 are revised to refer to SOP RA04. - Section 5.6: Definition of surrogate organ added. - Attachment 1: 'Target Organ Surrogate List' revised and moved to SM ID01. - Attachment 2: 'RDA Quality Assurance Checklist' is removed as it is included by reference as part of RA05. - Attachment 3: 'Model RDA Report' is removed as a standardized RDA Report template is included in SOP RA04. - All references to eye doses are removed. - Minor editorial changes.	03/31/2008	Paul K. Blake
1.2	- Section 7 – revised to include RDA Report Decision Summary Sheet - Minor editorial changes.	10/31/2008	Paul K. Blake
1.3	- Changed name to RA01 - Added Section 5.4 on determining the uncertainty method; revised references to RAs after deletion of RA01; revised language to address probabilistic uncertainty analyses. - Minor editorial changes	01/31/2010	Paul K. Blake
2.0	- Updated Sections 3 and 4 to reflect changes in RDA processes. - Added reference in Section 5.6 to SOP RA02 for diseased organs and tissues cross-referenced to the NTPR Standard Organs and the NIOSH-IREP cancer risk models. - Added information on skin dose contributed from internally deposited radionuclides in Section 5.7. - Revised references to the NTPR Policy and Guidance Manual (DTRA, 2007) to citing specific SOPs and SMs. - Updated NTPR Program SOPs. - Minor editorial changes.	04/30/2021	James D. Franks

Table of Contents

Table of Contents 3
1. Purpose/Summary 4
2. Scope 4
3. Responsibilities 5
4. Definitions 5
5. Procedure: Detailed Activity/Task Description 5
   5.1 Review Case Information 6
   5.2 Collect Additional Information 6
   5.3 Identify Exposure Scenario and Define Exposure Pathways 6
   5.4 Determine Uncertainty 6
   5.5 Assess External Whole Body Dose 7
      5.5.1 Dose Assessment Hierarchy 7
      5.5.2 Conduct Film Badge Dosimetry Analysis 8
      5.5.3 Reconstruct Additional External Whole Body Doses 8
      5.5.4 Calculate Total External Doses and Upper-Bound Doses 10
   5.6 Assess Dose from Intakes of Radioactive Materials 10
   5.7 Assess Dose to the Skin 10
   5.8 Prepare Draft RDA Report 11
   5.9 Perform Reviews 11
   5.10 Prepare RDA Report 12
   5.11 Transmit RDA Report 12
   5.12 Review and Respond to External Review Comments 12
   5.13 Transmit Final Draft RDA Report 13
6. Data and Records Management 13
7. Quality Control and Quality Assurance 14
   7.1 Internal and External Reviews 14
   7.2 Decision Summary Sheets 14
8. Referenced SOPs and Standard Methods from this Manual 14
9. References 15

Standard Operating Procedure

RA01 – Radiation Dose Assessment for Cases Requiring Detailed Analysis

1. Purpose/Summary

This standard operating procedure (SOP) provides the detailed activities and tasks required to perform the analysis of radiation dose and prepare a Radiation Dose Assessment (RDA) Report for Nuclear Test Personnel Review (NTPR) Program participants (generally veterans) whose cases require a full RDA. This SOP addresses the evaluation of radiation doses to the whole body, and skin from external exposure, and to internal organs from the intake of radioactive materials by inhalation and ingestion. It provides procedures for determining whether uncertainties are evaluated using fixed factors or by preparing a complete, probabilistic analysis of dose distributions. The procedure requires the adaptation of model dose assessment tools or development of new modules to calculate the radiation doses, along with associated uncertainties, for a range of activities performed by a participant in varied radiation environments. It requires the preparation of calculation worksheets tailored to the specific participant activities and radiation environments, organs considered, and organ location of the case.

This SOP is written for qualified radiation dose analysts who perform the tasks using the Standard Methods (SM) for Radiation Dose Assessment provided in Part II of this manual. Tasks include the modification or development of specific calculation tools, and preparation of tailored RDA Reports. The SOP also outlines quality assurance activities performed by technical and management personnel to assure conformance with procedures and methods, as well as established NTPR policies and guidelines.

2. Scope

This SOP applies to participant cases that cannot be performed using expedited processing methods (SOP RA02). It employs approved standard methods and documented data that address all aspects of radiation dose calculations to satisfy the requirements of Title 32, Code of Federal Regulations (CFR), Part 218 "*Guidance for the Determination and Reporting of Nuclear Radiation Dose for DoD Participants in the Atmospheric Nuclear Test Program"* (DoD, 2020). Radiation dose assessments provide full consideration of benefit of the doubt throughout the dose preparation process as implemented in response to DTRA guidance for assuring consistency with Department of Veterans Affairs (VA) (38CFR3.102) requirements (VA, 2020), DTRA's *NTPR Program Quality Assurance SOP* (DTRA, 2021), and DTRA's *NTPR Program Support and Management SOP* (DTRA, 2020a).

3. Responsibilities

A qualified radiation dose assessment analyst, or RDA Analyst, performs the majority of tasks required for analyzing the radiation exposure activities, calculating radiation doses, and preparing the RDA Report. Other RDA analyst conduct technical reviews for quality control to assure all exposure scenarios are taken into account and that the dose estimation methods are correctly applied. Another review is performed by a certified health physicist (CHP) to ensure the RDA is conducted according to best health physics practices and the results are sound. Management personnel perform a final review for quality assurance to verify that the RDA is performed in accordance with NTPR SOPs and SMs. Administrative staff assists with information retrieval, case management, and records management.

4. Definitions

CHP	Certified Health Physicist.
Enterprise Manager	NTPR/DTRA Program Manager. The NTPR Enterprise includes the DTRA NTPR Program Office and its contractors and subcontractors.
NuTRIS	Nuclear Test Research Information System is a veteran cohort search tool and database.
SPARE	A document with detailed information on an NTPR participant's activity scenario during involvement in the U.S. atmospheric nuclear testing program or occupation of Japan.

5. Procedure: Detailed Activity/Task Description

Radiation dose assessment starts with a review of the veteran's returned Scenario of Participation and Radiation Exposure (SPARE), evaluates any comments for possible changes to the scenario, determines the approach to dose uncertainty; and proceeds with dose calculations and preparation of the RDA Report. Doses are based on either recorded film-badge dosimetry or calculated using dose reconstructions methods. Dose estimates determined by dose reconstruction are performed using standardized analytical methods with documented assumptions, radiation intensities, and other calculation parameters.

As stated above, radiation dose assessments provide full consideration of benefit of the doubt throughout the dose estimating process as implemented in response to DTRA guidance for assuring consistency with VA (38CFR3.102) requirements (VA, 2020). To do so, radiation dose analysts consider veteran statements and use them unless the statements involve activities that are not plausible or refuted by documented records. High-sided parameter values and assumptions that maximize the veteran's dose are employed in calculations of dose and uncertainty using fixed factors. For probabilistic analyses, credible estimates of parameter distributions are used. Following are the steps

used to carry out a dose assessment and prepare an RDA Report and calculation worksheets according to the standardized templates provided in SOP RA03.

5.1 Review Case Information

The analyst reviews the returned SPARE for activities contained in the prepared document or added as comments by the veteran. The analyst reviews other case materials, project reports, previous radiation dose assessment reports, if available, and any other available documentation and determines:

- Whether all required information is available to carry out the dose assessment
- Whether any conflicts or inconsistencies continue to exist between the documented record and the veteran's statements
- Whether the scenario is amenable to use of fixed uncertainty factors or a complete probabilistic analysis is indicated. See Section 5.4 below for specifics.

5.2 Collect Additional Information

If additional information is needed to complete the case or resolve inconsistencies, the analyst:

- Searches available document repositories for the needed information including the Nuclear Test Research Information System (NuTRIS) database
- Requests other references from the NTPR Program library
- Identifies additional queries required of the veteran to be obtained through the program's veteran assistance unit (DTRA, 2020b).

5.3 Identify Exposure Scenario and Define Exposure Pathways

Radiation exposures are estimated based on scenarios that define the participant's activities in radiation environments applicable to the test operation and shot or shots in which the veteran participated. Radiation exposures are defined in terms of pathways of exposure that involve a source of radiation, a mechanism (pathway) for the radiation to reach the exposed individual, and, for internal dose assessment, a route of entry to the body. Parameters required to calculate the dose are obtained from records if available or are estimated based on reasonable assumptions using the principle of high-sidedness in cases using fixed uncertainty factors or credible distributions for cases using full probabilistic analysis.

5.4 Determine Uncertainty

Uncertainty in reconstructed doses is determined using either fixed uncertainty factors provided in Standard Method (SM) UA01 of this manual, or by using analyses based on a

probabilistic approach and Monte Carlo simulations (Weitz et al., 2009). Selection of the method is based on an evaluation, using dose reconstruction experience, of which method is expected to produce a credible upper-bound dose in the most expeditious manner. A credible upper-bound dose is one that is at least greater than the dose that 95 percent of the exposed population would have received. If both methods are expected to produce a credible upper-bound dose, then the fixed uncertainty factors method is preferred because it gets dose information to the VA faster. Conversely, for scenarios where use of fixed uncertainty factors is not expected to produce upper-bound doses that are credible, then the full probabilistic analysis method is selected.

When performing a radiation dose assessment, the analyst reviews the scenario, and radiation environment characteristics to assess the potential for conditions that may not result in a credible upper bound using the fixed uncertainty factors. Such scenarios may involve more complex exposure situations with many uncertain variables or may have historically shown that use of fixed uncertainty factors do not produce credible upper bounds. The analyst may consult with other RDA analysts in reaching a conclusion.

The analyst recommends the uncertainty analysis method to the dose reconstruction contractor's NTPR manager, who presents the recommendations to the DTRA program manager for concurrence. In some case, the DTRA NTPR program manager may direct that the probabilistic analysis method be used without consideration of the use of fixed uncertainty factors.

5.5 Assess External Whole Body Dose

External whole body dose represents the most common type of radiation exposure because the activities and location of atomic veterans with respect to detonations and resulting contamination made external exposure the most common source of exposure. Records of radiation intensity (exposure rate) measurements and personnel dosimetry are available and reliable for many of the atmospheric test operations.

5.5.1 Dose Assessment Hierarchy

Dose reconstruction regulations for the NTPR Program participants specify that radiation doses should be determined using the following hierarchy of methods:

- Dosimetry results for the individual, normally from film badge records
- Dosimetry results for members of a cohort such as a group of individuals who performed the same activities as the veteran of interest and who had potential for radiation exposure
- Reconstructed doses obtained using sound scientific methods and a knowledge of the activities and radiation environments to which the individual was exposed when individual and cohort dosimetry are unavailable.

5.5.2 Conduct Film Badge Dosimetry Analysis

If either individual or cohort film dosimetry records are available, the analyst uses SM ED01 to evaluate their reliability and to determine the dose and uncertainty for the time periods covered by the dosimetry and for the radiation types sensed by the dosimeter.

For time periods not covered by film badges or for which dosimetry records are deemed unreliable, radiation doses are estimated using dose reconstruction techniques as described in the following section.

5.5.3 Reconstruct Additional External Whole Body Doses

The analyst determines time periods during which the individual was not monitored by reliable personnel or cohort dosimetry. Radiation doses for these periods are assessed using reconstruction techniques described in this section.

5.5.3.1 Characterize Radiation Environment

Radiation dose assessments require that the initial radiation and residual radiation environments be properly defined and characterized. These types of radiation are described as follows:

- For the purposes of dose assessment, initial radiation is defined as gamma and neutron radiation emitted within one minute after a nuclear detonation.
- Residual radiation originates from radioactive clouds and fallout generated by a nuclear detonation, radiation from previously detonated shots, induced radiation from initial neutrons, and radioactive debris deposited in water during oceanic tests. Because residual radiation decays, the radiation environment is defined by the radiation intensity (exposure rate) as a function of type and time.

5.5.3.2 Identify Significant Exposure Activities

Based on the review of the returned SPARE combined with information in operational records, the analyst develops the veteran’s detailed activities in space and time and considers the following sources of external exposure:

- Initial neutron
- Initial gamma
- Residual gamma.

5.5.3.3 Develop Assumptions and Input Parameters

The scenario description in the RDA Report includes statements of all pertinent assumptions required to complete the dose assessment. When details of the components cannot be determined from the SPARE and other documented records, activities must be assumed. Examples of typical assumptions that need to be made or require additional veteran's input include:

- Location of meals and whether meals were eaten outdoors
- The location of individuals within a unit's movement during field maneuvers
- Specific jobs or assignments given to the veteran that were not given to the rest of his unit.

5.5.3.4 Estimate Doses by Reconstruction

Radiation dose analysts use SM ED02 to reconstruct doses and uncertainties from external radiations, both initial and residual.

Initial radiation doses (neutron and gamma) principally depend on participant positioning at the time of a nuclear detonation. The computer code ATR6 is used to estimate the surface radiation field environment from the radiation source term (Kaul et al., 1992). If troops are located in trenches, calculation tools are used to assess the environment in the trenches and to estimate the initial radiation doses. Thus, the initial gamma and neutron doses are estimated using approved computer codes such as ATR6 based on distance and posture of the troops during exposure to initial radiation.

Residual radiation results in gamma doses to the whole body including affected skin and internal organs. Residual radiation doses are principally dependent on the movement of troops within fallout or neutron activation fields in the shot areas or from the deposition of fallout on islands, ships, and lagoon waters. The movement of troops in the field commonly avoided high intensity radiation fields based on real-time radiation monitoring. The dose associated with every troop movement or activity is estimated and summed to obtain a total dose. The time-dependent radiation intensity (exposure rate) for a given location, such as residence island or ship is usually characterized by a single mean value (typical peak intensity) for measurements taken at the indicated elapsed time in hours after the detonation (H+h) (with a measured or estimated error). The mean intensity is then decay corrected to provide intensity as a function of time, as described in Section 5.2.1 of SM ED02. If measured intensities are not available for a particular location, they may be estimated using measured intensities taken on nearby ships or land areas (See SM ED02).

5.5.4 Calculate Total External Doses and Upper-Bound Doses

Once doses from film badges and for various exposure scenarios are determined, the analyst calculates the total external doses from neutron and gamma radiation sources. The analyst then estimates the upper-bound doses using SM UA01.

5.6 Assess Dose from Intakes of Radioactive Materials

For internally deposited radioactive materials, the analyst estimates dose from internal exposure pathways. The following pathways are considered:

- Inhalation of descending fallout
- Inhalation of suspended or resuspended radionuclides
- Inhalation of radionuclides in an atmospheric cloud
- Ingestion of radionuclides
- Absorption of radionuclides through skin or open wounds.

The analyst reviews the request for a dose assessment and determines the internal organs of interest. If dose conversion factors are not available for an organ of interest, a surrogate organ is substituted in the dose assessment. A surrogate organ is similar to the organ of interest with respect to its biokinetic modeling (see SM ID01 for a list of surrogate organs). In addition, Table Att 2-1 of SOP RA02 lists diseased organs and tissues cross-referenced to the NTPR Standard Organs used in FIIDOS internal dose calculations (see SM ID01) and the cancer risk models of NIOSH-IREP (NIOSH, 2002). Using SM ID01, the analyst calculates committed equivalent dose for each internal organ or surrogate separately for alpha particles, and for beta particles plus gamma rays for each pathway. The analyst then estimates each organ's total doses for all pathways and determines upper-bound doses using the methods described in SM UA01.

5.7 Assess Dose to the Skin

Based on the review of the returned SPARE combined with information in the operational records, the analyst develops the participant's detailed activities in space and time and considers the following sources of external exposure to the skin:

- Residual beta and gamma activity on contaminated surfaces
- Descending and resuspended radioactive materials deposited on the skin.

Skin doses are composed of gamma and beta doses. Gamma doses are those estimated for the whole body as described above. Beta doses to the skin are calculated based on the following factors:

- Characterization of the external gamma environment and whole body gamma dose.
- Beta-to-gamma dose ratios, which are time-dependent
- Effect(s) of shielding from beta particle radiation
- Anatomical location(s) where a "beta burn" or skin cancer has been diagnosed by a physician
- Participant postures in a radiation environment, e.g., standing, sitting, working off a high platform, etc.
- Source geometry and scale
- Contribution to dermal contamination by direct contact to the skin from deposition of descending fallout or resuspended materials.

Once all assumptions and parameters are gathered from available documentation and the returned SPARE, including veteran's input and comments, the analyst calculates the beta doses and the total beta-plus-gamma doses from each exposure type and for each affected skin location. The analyst uses SM ED03 to calculate the dose for direct exposure to surface-deposited radioactivity and SM ED04 for dose resulting from contaminants deposited on the skin.

Once radiation doses are estimated for each skin exposure pathway, the analyst calculates the combined total dose for each identified skin location. The analyst then estimates the upper-bound doses using SM UA01.

Notice that internal dose from contaminants that were inhaled or ingested by the veteran during his participation in atmospheric nuclear weapon testing contributed less than one percent to his total skin dose (Raine et al., 2007).

5.8 Prepare Draft RDA Report

Once all dose calculations are completed using worksheets prepared according to SOP RA03, the analyst drafts an RDA Report that contains all dose results and pertinent scenario information and assumptions. A detailed description of how to prepare RDA Reports and a standardized template is provided in SOP RA03.

5.9 Perform Reviews

The analyst submits the draft RDA Report and dose calculations to another qualified radiation dose analyst for technical review as described in SOP RA04.

The analyst revises the draft RDA Report and dose calculations to address comments from the technical review, and then submits the revised draft RDA Report and dose calculations for review by a Certified Health Physicist (CHP) as described in SOP RA04.

The analyst revises the draft RDA Report and dose calculations to address comments from the review by a CHP, and then submits the revised draft RDA Report and calculations for Management Review as described in SOP RA04.

Each reviewer documents comments and suggested revisions on the draft documents, and records completion of the review on a QA checklist. Reviewed copies are initialed and dated. The responsible analyst retains the reviewed copies at each level as provided in SOP RA04.

5.10 Prepare RDA Report

The analyst revises the draft RDA Report and dose calculations to address comments from the Management Review, prepares a final RDA Report, and assembles all relevant information for transmittal to the Enterprise Manager.

5.11 Transmit RDA Report

Once the final RDA Report is completed, Administrative staff personnel perform the following tasks in accordance with NTPR Program Support and Management SOP DTRA (2020a) and NTPR Program Quality Assurance SOP DTRA (2021):

- Prepare an official electronic version (portable document format (pdf) or an approved equivalent format) of the final RDA Report and supporting dose calculation worksheet(s), and make hardcopy records for filing
- Place electronic documents into the temporary archive pending completion of external reviews
- Transmit documents to the Enterprise Manager. Documents are transmitted electronically but can be transmitted in hardcopy if needed.

5.12 Review and Respond to External Review Comments

If the final RDA Report is returned from external QA review with comments, complete the remaining steps described in this section. Note that external QA review may approve the RDA Report for submission to DTRA. In such a case, no further actions are required.

External QA review comments on final RDA Reports returned to the dose reconstruction team are categorized as those requiring: a) editorial changes only and forwarding to DTRA, b) resolution of administrative issues such as dates or units and return for review, or c) revision of the RDA Report per comments and resubmission for review. The following actions are taken based on the type of the comments received:

a) Editorial Changes only

- The case is returned to the analyst who reviews the suggested editorial changes, determines possible impacts on the overall report, and prepares a revised final RDA Report.

- The analyst submits the revised final RDA Report for Management Review.
- If Management Review provides comments, the analyst resolves the comments and submits the final RDA Report for transmittal to the Enterprise Manager.

b) Resolution of Administrative Issues

- The case is returned to the analyst who reviews the administrative issues, develops resolutions, determines possible impacts on the overall report, and prepares a revised RDA Report.
- The analyst submits the final RDA Report for Management Review.
- If Management Review provides comments, the analyst resolves the comments and submits the final RDA Report for transmittal to the Enterprise Manager.

c) Revision of the RDA Report per Comments

- The case is returned to the analyst who reviews the suggested changes, determines possible impacts on the overall report, and prepares a revised RDA Report.
- The analyst submits the revised RDA Report for Management Review. If substantial revisions in the technical content of the dose calculations are required, management may request a technical review according to SOP RA04.
- If Management Review provides comments, the analyst resolves the comments and submits the final RDA Report for transmittal to the Enterprise Manager.

5.13 Transmit Final Draft RDA Report

Once the final RDA Report is completed, administrative staff personnel perform the following tasks:

- Prepare an official electronic version (portable document format (pdf) or equivalent approved format) of the RDA Report and supporting dose calculation worksheet(s), if any were required during the revision process.
- Complete transmittal of documents to the Enterprise Manager. Documents can be transmitted in hardcopy if needed.
- Make hardcopy records for filing. File hardcopies in the dose reconstruction contractor's library.

6. Data and Records Management

This SOP is used to produce RDA Reports and dose calculation worksheets in electronic form, although paper documents may be used in special circumstances. In addition, other case documents, including the SPARE, data tables, supporting reports, etc., may be used.

Such documents are assembled into hardcopy case files stored by the dose reconstruction team.

Official copies of the final RDA Report, dose calculations, and supporting information are maintained by the Enterprise Manager.

7. Quality Control and Quality Assurance

7.1 Internal and External Reviews

Quality control checks are built into the calculation tools used in estimating the radiation doses. Additional reviews include those conducted by peer analysts from the dose reconstruction team as described in SOP RA04. Consistency and conformance with policies and guidelines are further assured through management reviews.

Independent external reviews are performed according to the NTPR Program Quality Assurance SOP (DTRA, 2021) and as described in Section 5. The RDA Reports and calculations are revised in response to significant comments from the external review as described in section 5.12. For the purpose of this procedure, external reviews are conducted by qualified analysts who are not part of the dose reconstruction team. Significant comments are those that impact major elements of information provided in the RDA Report, and those that materially affect the dose calculation results in a manner that is not already built into the uncertainty calculations.

7.2 Decision Summary Sheets

A Decision Summary Sheet (DSS) system has been implemented and is described in the NTPR Program Quality Assurance SOP (DTRA, 2021). This system documents the critical decisions made for each case to maintain consistency, reproducibility, and comprehensibility of the dose assessment processes. As part of this process, the analyst prepares an RDA Report DSS capturing all important decisions along with the rationale used and assumptions and references needed to reach each decision. The RDA DSS documents dose assessment decisions for a specific case and permits reviewers and auditors to easily evaluate the analyst's rationale and eventually reproduce doses if needed. A standard template of the RDA Report DSS is included in SOP RA03.

8. Referenced SOPs and Standard Methods from this Manual

(1) SOP RA02 - Expedited Processing of Radiation Dose Assessments for Atmospheric Nuclear Weapons Testing Veterans

(2) SOP RA03 - Standardized Radiation Dose Assessment Reports and Dose Calculation Worksheets

(3) SOP RA04 - Internal RDA Reviews

(4) SM ED01 - Film Badge Dose Assessment

(5) SM ED02 - Whole Body External Dose Assessment

(6) SM ED03 - Skin Dose from External Sources

(7) SM ED04 - Skin Dose from Dermal Contamination

(8) SM ID01 - Doses to Organs from Intake of Radioactive Materials

(9) SM UA01 - Dose Uncertainty and Upper-Bound Dose Determinations

9. References

DoD (Department of Defense), 2020. "Guidance for the Determination and Reporting of Nuclear Radiation Dose for DoD Participants in the Atmospheric Nuclear Test Program (1945-1962)." Title 32, Code of Federal Regulations, Part 218. Washington, DC. July 1.

DTRA (Defense Threat Reduction Agency), 2020a. DTRA NTPR Program Support and Management SOP (Rev. 6). Defense Threat Reduction Agency, Fort Belvoir, VA. October 30.

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Weitz, R.L.; Case, D. R.; Chehata, M.; Egbert, S. D.; Mason, C. L.; Singer, H. A.; Martinez, D. G.; McKenzie-Carter, M. A.; and Stiver, J. S., 2009. *Probabilistic Approach to Uncertainty Analysis in NTPR Radiation Dose Assessments.* DTRA TR-09-13. Defense Threat Reduction Agency, Fort Belvoir, VA. November 1.