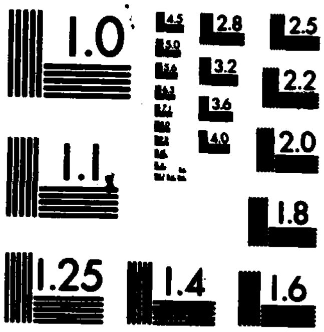
AD-A128 908 DIRECT COURSE AND DUST EXPERIMENTS(U) MITRE CORP MCLEAN 1/1
VA D EARDLEY ET AL. APR 83 JSR-82-402

UNCLASSIFIED F/G 4/2 NL

END
DATE
FILMED
DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Direct Course and Dust Experiments

D. Eardley
J. Katz

April 1983

JSR-82-402

Approved for public release; distribution unlimited.

DNA

JASON
The MITRE Corporation
1820 Dolley Madison Boulevard
McLean, Virginia 22102

TABLE OF CONTENTS

1.0 INTRODUCTION

This informal note contains our comments on the DNA experimental program designed to improve the understanding of the lofting and distribution of dust by airburst explosions. It is a sequel to ~~our~~ AN earlier report "Dust from Low Altitude Bursts" (JSR-81-30), which discussed at greater length the nature of the dust problem, the limited body of experimental data, and suggestions for an experimental program. At that time we were particularly concerned with the problem of radar transmission through dust pedestals. Since then the Direct Course experiment has been planned in order to gather new data. The purpose of this report is to comment on the plans for this experiment and for further experimental work. We are concerned not only with radar transmission problems, but also with the high altitude dust problems which arose in connection with Closely Spaced Basing (Dense Pack), and with dust problems in general.

2.0 *DIRECT COURSE EXPERIMENTS*

The Direct Course shot will employ 600 T of high explosive (ANFO), which will have about the same hydrodynamic effects as 1 kT nuclear, at a HOB of 166 ft. It will be very well instrumented for early time dust effects close to the ground and for overpressure measurements. However, these measurements will be over prepared disturbed surfaces, and measurements will not be made on totally natural surfaces. It will also have measurements of radar beam propagation through the late time cloud, and some radar mapping. However, direct sampling of the late time cloud will not be carried out, according to current plans.

2.1 Early Time Dust and Flow Field Measurements

Direct Course will have a wide variety of high time resolution experiments close to the ground for measurement of dust loading, air flow, and dust flow close to the ground as a function of time. These experiments seem well planned for the stated purposes. Our only comments are 1) this is only one shot, whereas the DNA dust effort would benefit from greater continuity of effort, with more laboratory-scale experiments along these lines; and 2) similar measurements should also be taken over totally natural surfaces.

2.2 Late Time Dust

Direct Course will provide an opportunity to characterize quantitatively a large late time dust cloud, and in particular to carry out some measurements which should have been carried out (in hindsight) during the atmospheric nuclear testing program. An important question which we have not heard discussed sufficiently, is to what degree the late time HE dust cloud resembles a nuclear dust cloud. Loading of the ascending cloud by HE detonation products must certainly affect its rate of rise, equilibration altitude, and equilibration radius. Therefore the late time flow field, in particular the late time vortex which is important in bringing dust to altitude, may differ from that of a nuclear burst. A 1 kT nuclear cloud will equilibrate at an altitude of ~ 2 mi; will Direct Course produce the same result? On the other hand, this shot has been calibrated for similar air flow close to the ground at distances great enough from ground zero, so that the fidelity of the dust pedestal should be good.

The late time dust will be characterized by several means. Photography is, of course, useful, but it provides mainly qualitative information. BMD proposes to carry out a series of experiments which are primarily intended to study radar propagation through the dust cloud (as in the LoADS system). Radar beam measurements will measure both the integrated dust density along certain lines of sight (at both low and high angles to the ground), and the fluctuation spectrum of dust density as it affects radar propagation. These radar beam experiments will provide useful information for BMD system studies and will also give some idea of the gross late time dust distribution in the air. However, data will be measured only along a few lines of sight, and more global measurements of dust distribution are also required.

Radar mapping of the entire cloud provides a promising proposal. The advantage is that a global picture of dust distribution and velocity can be obtained; the disadvantage is that calibration of results may be very difficult, so that in worst case only qualitative information similar to optical photography may be produced. Calibration will be difficult because radar return will depend both on total dust loading and on dust particle size distribution at altitude. Use of multiple radar frequencies may allow a separate determination of mean particle size. Use of multiple aspects may also help to resolve geometrical ambiguities. We feel that radar mapping is highly desirable, in that it is the only available technique which can, in principle, make quantitative measurements of both density and velocity in the whole dust cloud; but we also feel that problems of calibration and interpretation will be serious and must be addressed.

2.3 Sampling of Late Time Dust Cloud

We recommend that the late time dust cloud be directly sampled. This will measure the dust particle size distribution, which will be of great help in interpreting and reducing the radar measurements, and will also provide an independent means of estimating the total dust loading. Sampling probes could be propelled into the cloud by several means, including rockets, mortars, or free-fall from helicopters or balloons. We are told that all these are forbidden due to rules for range safety or danger to other experiments; however, it seems to us that the value of samples is great enough that ways of getting them should be found. Sampling probes could collect dust by any of several means, including filters, stagnation chambers, sticky or soft noses, or explosively closed tubes; either instantaneous samples or samples integrated along the flight trajectory could be obtained. An important consideration in choice of sampling method is bias for particle size; e.g., a fast probe with a soft (plastic foam?) nose would entrap and collect big particles but not small ones, because small particles follow the airstream more closely.

2.4 Raising Dust and Pebbles

Since planning for Direct Course began, studies on Closely Spaced Basing (CSB) of MX (Dense Pack) have created a great new interest in dust and debris as a means of defense for missile fields. Previously, one thought of dust and debris as a side effect of the attack which complicated and aggravated the task of the defender. (However, "buried bombs" defense of missile fields is a possible use of debris which has been discussed for several years.) In CSB, dust and debris are primarily a complication and aggravation for the attacker, and the defender may wish to take positive measures to raise more dust and debris. Total sweep-up rate for dust is $\gtrsim$ 0.01 Mt dust/Mt yield, so any deliberate modification or preparation of the surface must use cheap materials and methods. Two obvious possibilities are 1) build hills or dikes of ambient soil, and 2) build hills or dikes of gravel or pebbles. Direct Course offers an opportunity to try out some such ideas; is it possible to build some hills of fine gravel along some otherwise unused radial, to see how far gravel is moved? Imported gravel of a different color than ambient material could be used to facilitate post-shot sampling; or perhaps gravel could be painted or dyed. The question of particle size is, as usual, a troublesome one (see review and discussion in JSR-81-30). Small enough particles should be used so that suspension rather that saltation occurs. If particle size d is scaled as $d \propto Y^{1/3}$, then hydrodynamic effects will scale correct but gravity will be wrong; if d is not scaled with yield Y, then gravity will scale correctly but the hydro will be wrong. The former scaling will probably be preferred since the purpose is to get the material up in the air, and hydrodynamics dominates the sweep-up.

3.0 WHAT DO WE WANT TO KNOW?

There are several distinct objectives to a dust measurement program. If we consider only the dust proper, and ignore its effects on the air flow field (the effect of the nonideal boundary condition), these objectives include the following:

The total quantity of dust lofted and its gross spatial distribution. These are needed in order to determine high altitude dust erosion of re-entry vehicles and missiles, which is a cause of fratricide in many hypothesized attacks on Dense Pack. The great uncertainty in high altitude dust lofting has added serious ambiguities to these questions.

The spatial distribution of dust density on scales of centimeters and meters. This must be known in order to determine the radar propagation properties of dust clouds. Propagation problems are largely the result of refraction by heterogeneities in dust density and refractive index.

The physics of dust lofting. This includes the processes of thermal popcorning, reverse pore pressure lofting, and boundary layer shear sweep-up. An understanding of these processes would be a very powerful tool which would, in principle, permit theoretical calculation of dust densities and distributions in a wide variety of problems, including those not yet anticipated.

Multi-burst dust environments. The effects of more than one nuclear burst in a small region and over a short time are not simply additive; there is essentially no understanding of how they interact. Systems such as Dense Pack depend on environments with many interacting bursts, in which fireballs merge, shocks intersect, dust from one burst enters the flow field of others, etc.

4.0 HOW DO WE FIND OUT?

Each of these questions requires a different approach. Some will be directly addressed by the Direct Course experiment, while others would require different experiments. Here we comment briefly on each in turn:

As has been the case with earlier dust experiments, the dust density in the sweep-up layer near the surface will be measured with several different kinds of instruments. Those planned for Direct Course are notable for their number and variety of experimental technique (X-rays, β-rays, radar, radiofrequency refraction, sample tubes, SNOB and GREG gauges, optical extinction and scattering, holography, and photography). Near-surface dust has important consequences for near-surface dynamic pressure and radar transmission, but its knowledge does not tell one how much high altitude dust there is. Rough estimates suggest that only 10^{-3} of the near-surface dust remains aloft at long times and high altitudes. This fraction is very poorly known, and important to determine.

In order to estimate the quantity of high altitude dust two techniques are promising. One is mapping of the entire cloud by radar scattering. This offers the possibility of measuring both the total amount lofted and its spatial distribution within the rising cloud. The second is the penetration of the cloud by rockets carrying dust samplers, either collection tubes or filters. The two techniques support each other, because the distribution of particle sizes (best measured by direct sampling, and not necessarily the same as that of the undisturbed surface) is necessary to a quantitative interpretation of the radar data.

It is unfortunate that the final height and shape of the dust cloud do not scale with yield, because they depend on the temperature structure of the atmosphere (the scale height is a natural length). This will add an irremovable element of uncertainty to interpretation of high altitude dust results. Though significant, we think this uncertainty will be much less than the present order-of-magnitude uncertainties in high altitude dust. This is because the mass lofted above the surface boundary layer may scale with yield, and small particles, once lofted, fall out slowly regardless of the precise evolution of the airflow. Therefore, we expect measurements of dust lofting in high explosive experiments to give useful information about nuclear bursts.

In our previous report we discussed the problem of radar propagation through turbulent dust clouds, and concluded that the best experiment would be radar propagation. We recommended that more than one wavelength be used, and that the wavelength be scaled as the cube root of yield, along with other lengths characterizing the gross flow, and presumably the turbulence. The geometry should be scaled as well as possible, preserving the beam angles through the dust cloud.

We think that the microscopic physics of dust lofting is best studied in a series of small laboratory or field experiments in which wind shear and overpressure are produced in wind tunnels or shock tubes. This would permit the gradual and simultaneous development of experimental technique and theoretical understanding, as results from each experiment aid the design of subsequent ones.

Multiburst problems are inherently specific to systems or attack scenarios. Direct Course will not directly answer multiburst questions. It is possible to design further experiments involving numbers of small charges, suitably spaced and timed, which can answer specific questions.

5.0 RECOMMENDATIONS

5.1 Direct Course

We have two recommendations for this experiment. One is that an effort be made to include direct rocket sampling of the dust density in the cloud. This will yield useful data, and will complement the radar cloud mapping experiment. The second concerns surface preparation. As is well known, an undisturbed desert surface has very different properties, and is much less dusty, than a disturbed surface. It is not possible to conduct the entire Direct Course experiment over an undisturbed surface, which would be the most realistic approximation to an actual wartime nuclear burst. Thus, overall dust cloud properties and mass loading will reflect the large portion of unavoidably disturbed surface in the Direct Course experiment. It is possible, and we think important, to set aside a radial consisting of the native desert surface, untouched except for the installation of diagnostics (and perhaps fenced). This would permit the comparison of dust lofting from the native surface with that from the various prepared surfaces. We are less concerned by the presence of vegetation than we would be by the disturbance required to remove it. If the most important natural surfaces are free of vegetation, and this is considered important, then at some time in the future an experiment should be performed over such a surface, in the geographical area of interest.

5.2 Future Experiments

We recommend a long term, small scale, laboratory and field experimental program to measure the physical processes involved in dust lofting from realistic surfaces. It will probably be most convenient to use wind tunnels or shock tubes as the source of air flow. The purpose of this program should be to develop and verify dust lofting models which can be used with some confidence in hydrodynamic codes like DICE.

In future dust HOB experiments radar scattering is the most promising means of mapping the dust cloud density. It should be supported by rocket probes. It may also be possible to measure line-of-sight integrated dust density using the radiofrequency phase shift technique, placing source or receiver on a tower or hill. It is necessary to allow for source and receiver motion and refraction in shocked air. Towers are probably not stiff enough to reduce motion to an acceptable level.

We recommend that a series of modest yield experiments be conducted at several heights of burst, and perhaps over more than one type of surface. We were struck during our consideration of

Dense Pack that Direct Course is planned to be at a different scaled height of burst and over a different surface than the bursts whose effects we wanted to know. A "library" of dust results with varying parameters will be useful during the next unanticipated crisis. The use of data from experiments of smaller yield (like pre-Direct Course, for example) rather than kiloton yield requires some faith in scaling laws, but not much more than is required to apply the results of kiloton experiments to megaton explosions.

APPENDIX

Briefing on Direct Course and Dust Experiments
JASON Summer Study, La Jolla, California
July 15, 1982

Briefers:

Overview of Test Objectives: George Ullrich, DNA; Jerry Carpenter, RDA

Source Design:
- HE-Nuclear Equivalence: Allen Kuhl, RDA
- Tower Interference Effects: John Wisotski, Denver Research Institute

Test Bed Layout: Capt. Grayson, Field Command, DNA

Dust Diagnostic Techniques:
- Photo Diagnostics: John Wisotski, Denver Research Institute; W. Dudziak, ISI
- Dust Capture Tubes: John Wisotski, Denver Research Institute
- X-ray Transmission: H. Helava, Physics International

Dust Diagnostic Techniques:
- Greg/Snob Gages: B. Hartenbaum, H-Tech
- Hot Film Shear Gauge: Dick Batt, TRW
- Optical Transmission/Scattering/Holography: Ralph Wuerker, TRW
- Beta Densitometer: G. Walford, Gull/SAI

Dust Diagnostic Techniques:
- Radar Cloud Mapping: J. Cockayne, SAI
- Radar Transmission: A. Burns, SRI
- Passive Dust Measurements: G. Ullrich, DNA

JASONs Present:

D. Eardley
J. Katz
M. Ruderman

Distribution List

Dr. Alf Andreassen
Technical Director, OPNAV-095X
Room 5D616, The Pentagon
Washington, D.C. 20350

Dr. Marvin Atkins
Deputy Director, Science & Tech.
Defense Nuclear Agency
Washington, D.C. 20305

Director, BMD Systems Command
P.O. Box 1500
Huntsville, AL 35807
ATTN: BMDSC-HLE

Director, BMD Systems Command
P.O. Box 1500
Huntsville, AL 35807
ATTN: BMDSC-HW

Science Applications, Inc.
P.O. Box 1303
La Jolla, CA 92038
ATTN: J. Barthel

TRW Systems Group
One Space Park
Redondo Beach CA 90278
ATTN: R. Batt

David Book
Naval Research Laboratory
4555 Overlook Ave. S.W.
Code 4040
Washington, D.C. 20375

Pacific Sierra Research, Inc.
1456 Cloverfield Blvd.
Santa Monica, CA 90404
ATTN: Hal Brode

CDR Paul Brouwer
NFOIO Detachment, Suitland
4301 Suitland Road
Washington, D.C. 20390

SRI International
333 Ravenswood Avenue
Menlo Park, CA 94025
ATTN: A. Burns

R&D Associates
P.O. Box 9695
Marina del Rey, CA 90291
ATTN: H. Carpenter

Science Applications, Inc.
1710 Goodridge Drive
McLean, VA 22102
ATTN: J. Cockayne

Dr. Robert Cooper [2]
Director, DARPA
1400 Wilson Boulevard
Arlington, VA 22209

CDR Robert Cronin
Dep Asst Secy Navy (C^3I)
Office of Asst Secy Navy
for RE&S
Room 4E749, The Pentagon
Washington, D.C. 20350

Kaman Tempo
816 State
P.O. Drawer QQ
Santa Barbara, CA 93107
ATTN: DAS IAS

Director
U.S. Army Ballistic Research Lab.
Aberdeen, MD 21005
ATTN: DRDAR-BLT

Defense Technical Information [2]
Center
Cameron Station
Alexandria, VA 22314

Distribution List

The Honorable Richard DeLauer
Under Secretary of Defense (R&E)
Office of the Secretary of
Defense
Room 3E1006, The Pentagon
Washington, D.C. 20301

Information Science, Inc.
123 W. Padre Street
Santa Barbara, CA 93105
ATTN: W. Dudziak

Dr. Douglas Eardley
100 Elinor Road
Newton Highlands, MA 02161

Dr. David D. Elliott
SRI International
333 Ravenswood Avenue
Menlo Park, CA 94025

Defense Nuclear Agency
Field Command
Kirtland AFB, NM 87115
ATTN: FCT

Defense Nuclear Agency
Office of the Director
Hybla Valley Federal Bldg.
6801 Telegraph Road
Alexandria, VA 20305
ATTN: Carl Fitz

Headquarters
Defense Nuclear Agency
Washington, D.C. 20305
ATTN: R. Flory

Director
National Security Agency
Fort George Meade, MD 20755
ATTN: Mr. Richard Foss, A05

Mr. Charles A. Fowler, A220
The MITRE Corporation
P.O. Box 208
Bedford, MA 01730

Mr. Larry Gershwin
P.O. Box 1925
Washington, D.C. 20013

Dr. S. William Gouse, W300
The MITRE Corporation
1820 Dolley Madison Blvd.
McLean, VA 22102

Commander, Field Command
Defense Nuclear Agency
Kirtland AFB, NM 87117
ATTN: R. Grayson

AFWL/NTED
ATTN: Lt. Robert Guice
Kirtland AFB, NM 87117

McDonnell-Douglas Corp.
5307 Bolsa Ave.
Huntington Beach, CA 92647
ATTN: R. Halprin

Dr. Edward Harper
OPNAV-021T
The Pentagon, Room 4D544
Washington, D.C. 20350

H-Tech Laboratories
P.O. Box 1686
Santa Monica, CA 90406
ATTN: B. Hartenbaum

Physics International Co.
2700 Merced Street
San Leandro, CA 94577
ATTN: H. Helava

Distribution List

Mr. R. Evan Hineman
P.O. Box 1925
Washington, D.C. 20013

The MITRE Corporation [25]
1820 Dolley Madison Boulevard
McLean, VA 22102
ATTN: JASON Library

Dr. Jonathan I. Katz
Department of Physics
Washington University
St. Louis, MO 63130

Mr. John F. Kaufmann
Dep. Dir. for Program Analysis
Office of Energy Research
(ER-31, MS A1-4000)
U.S. Department of Energy
Washington, D.C. 20545

Dr. George A. Keyworth
Director
Office of Science & Tech. Policy
Executive Office of the President
Washington, D.C. 20500

R&D Associates
P.O. Box 9695
Marina del Ray, CA 90291
ATTN: A. Kuhl

Mr. Ray Leadabrand
SRI International
333 Ravenswood Avenue
Menlo Park, CA 94025

Dr. Donald M. LeVine, W385 [3]
The MITRE Corporation
1820 Dolley Madison Blvd.
McLean, VA 22102

Dr. Verne L. Lynn
Deputy Director, DARPA
1400 Wilson Boulevard
Arlington, VA 22209

Dr. Gordon MacDonald, W300
The MITRE Corporation
1820 Dolley Madison Boulevard
McLean, VA 22102

Dr. Joseph Mangano [2]
DARPA/DEO
1400 Wilson Boulevard
Arlington, VA 22209

Defense Nuclear Agency
Office of the Director
Hybla Valley Federal Bldg.
6801 Telegraph Road
Alexandria, VA 20305
ATTN: Jack Mansfield

Mr. John McMahon
Dep. Dir. Cen. Intelligence
Washington, D.C. 20505

Director
National Security Agency
Fort Meade, MD 20755
ATTN: William Mehuron, DDR

The Aerospace Corporation
M5-743
P.O. Box 92957
Los Angeles, CA 90009
ATTN: Dr. Harold Mirels

Dr. Julian Nall [2]
P.O. Box 1925
Washington, D.C. 20013

Director
National Security Agency
Fort George G. Meade, MD 20755
ATTN: Mr. Neuberg, RSA FANX III

Distribution List

Prof. William A. Nierenberg
Scripps Institution of
Oceanography
University of California, S.D.
La Jolla, CA 92093

Science Applications, Inc.
P.O. Box 1303
La Jolla, CA 92038
ATTN: K. D. Pyatt

Cal. Research & Tech. Inc.
6269 Variel Ave.
Woodland Hills, CA 91367
ATTN: M. Rosenblatt

M. T. Sanford
Los Alamos Scientific Laboratory
P.O. Box 1663
Los Alamos, NM 87545

Physics International Co.
2700 Merced Street
San Leandro, CA 94577
ATTN: F. Sauer

Dr. Eugene Sevin
Defense Nuclear Agency
Washington, D.C. 20305

ADM William N. Small
Vice Chief of Naval Operations
Room 4E644, The Pentagon
Washington, D.C. 20350

Dr. Joel A. Snow
Senior Technical Advisor
Office of Energy Research
U.S. DOE, M.S. E084
Washington, D.C. 20585

Mr. Alexander J. Tachmindji, W300
Vice President & General Manager
Washington C^3I Operations
The MITRE Corporation
1820 Dolley Madison Boulevard
McLean, VA 22102

Dr. Al Trivelpiece
Director, Office of Energy
Research, U.S. DOE
M.S. 6E084
Washington, D.C. 20585

Mr. George Ullrich
Defense Nuclear Agency
Washington, D.C. 20305

Dr. James P. Wade, Jr.
Prin. Dep. Under Secretary of
Defense for R&E
Room 3E1014, The Pentagon
Washington, D.C. 20301

Science Applications, Inc.
800 Oak Ridge Turnpike
Suite 1000
Oak Ridge, TN 37830
ATTN: G. Walford

Maj. Gen. Jasper A. Welch, Jr.
Assistant Deputy Chief of Staff
for Research, Development,
and Acquisition
The Pentagon, Room 4E334
Washington, D.C. 20330

Denver Research Institute
University of Denver
P.O. Box 10127
Denver, CO 80210
ATTN: J. Wisotski

Distribution List

TRW Systems Group
One Space Park
Redondo Beach, CA 90278
ATTN: R. Wuerker

Mr. Leo Young
OUSDRE (R&AT)
The Pentagon, Room 3D1067
Washington, D.C. 20301

Mr. Charles A. Zraket
Executive Vice President
The MITRE Corporation
P.O. Box 208
Bedford, MA 01730

END

DATE
FILMED

7-83

DTIC