Report SDSMT/IAS/R-93/01

March 1993

ANNUAL PROGRESS REPORT ON ARMORED T-28 AIRCRAFT FACILITY COOPERATIVE AGREEMENT (ATM-9104474)

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Prepared for:

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ABSTRACT

This is the annual progress report required under the terms of Cooperative Agreement No. ATM-9104474 between the National Science Foundation (NSF) and the South Dakota School of Mines and Technology (SDSMT). This agreement provides for the operation of the SDSMT armored T-28 meteorological research aircraft as a national facility for investigations into cloud, thunderstorm, and hailstorm processes. This report covers the period 16 February 1992 through 15 February 1993. During this period, the T-28 provided flight support for a research project in Colorado, designed by the Research Applications Program at the National Center for Atmospheric Research to test radar algorithms for hail detection. It also performed some instrumentation test flights in the same area. Maintenance and development work included refurbishment and re-installation of a longer-blade propeller, development of an imaging capability for the hail spectrometer instrument, and development of state-of-the-art processing techniques for data acquired by the Particle Measuring Systems, Inc., Forward Scattering Spectrometer Probe carried on the T-28. Analysis of data from prior research projects continued and a number of publications and conference presentations based on the results of those analyses were prepared.

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1. INTRODUCTION

This annual progress report on T-28 research aircraft facility activities under Cooperative Agreement No. ATM-9104474 covers the period 16 February 1992 through 15 February 1993. Substantial reduction of data from the two 1991 field projects supported by the T-28 was accomplished during this period, as well as the preparation of publications and conference presentations based on projects spanning the period 1989 through 1991. Maintenance and refurbishment of various systems brought the aircraft back into shape after a very busy 1991 field season. Instrumentation and software development efforts continued, with emphasis on the microphysics sensors and calibration of the electric-field-measuring system. A brief two-week deployment to Greeley, Colorado, was undertaken to perform instrumentation tests, practice cooperative aircraft/radar flight coordination with the Colorado State University (CSU)/National Science Foundation (NSF) CHILL radar facility, and support the radar hail-detection research program being conducted by the Research Applications Program (RAP) of the National Center for Atmospheric Research (NCAR).

Summaries of these and other facility activities are presented in the following section. Plans for the third year of work under this agreement and required supporting information are presented in subsequent sections.

2. PROGRESS THROUGH THE YEAR

2.1 Project Support

At the request of V. Chandrasekar, Professor of Electrical Engineering at Colorado State University, and A. Detwiler, T-28 facility scientist, funds were made available from the NSF Division of Atmospheric Sciences (ATM) facilities deployment pool for a one-week field exercise during the summer of 1992. The T-28 flew clear-air and thunderstorm missions in cooperation with the CSU/NSF CHILL radar facility to test T-28 microphysical instrumentation, telemetry of aircraft position information between the aircraft and CHILL, and display of aircraft tracks on the CHILL PPI display.

In late May, a few weeks prior to the scheduled deployment, an arrangement was made with the RAP group at NCAR to provide support to a multiparameter radar hail-detection project in the Front Range region of Colorado (RAPS-92). The request was submitted by Ed Brandes of RAP. Funding was obtained to lengthen the T-28 Colorado deployment to two weeks, with the second week of flights being allocated primarily to RAPS-92 support.

The base of operations was the municipal airport at Greeley, Colorado, approximately 2 km south of the CHILL radar site. The deployment extended from 15 to 26 June. Table 1 gives a summary of flight activity, including a trip to Bismarck, North Dakota, just prior to the deployment for installation of the GPS/LORAN navigation unit. A summary of operations and catalog of data obtained has been prepared (Detwiler *et al.,* 1992).

2.1.1 Software/Hardware Test

The first week of the Greeley deployment was used to test instrumentation and refine aircraft tracking and radar coordination procedures. The T-28 air-to-ground telemetry system was tested and a vibration-related hardware problem subsequently identified that explained the progressive loss in performance of the system experienced during projects in 1991. Engineers with the CHILL facility developed the software to plot aircraft GPS positions telemetered from the T-28 to the CHILL site on the radar displays. Troubles with P-static (precipitation-induced static) hampered VHF/AM radio communications on numerous occasions; this recurring problem led to our request for FM radio systems in the equipment budget for the next year. Calibrations and performance tests were

TABLE 1: T-28 Flights, June 1992

Date (1992)	Flight No.	Hours	Purpose
2 June	582	1.4	Ferry RAP - BIS
9 June	583	1.4	Ferry BIS - RAP
15 June	584	2.0	Ferry RAP - GXY
17 June	585	1.1	Test
18 June	586	1.3	Test
20 June	587	2.2	Research RAPS-92
21 June	588	1.6	Research RAPS-92
22 June	589	1.6	Research RAPS-92
24 June	590	2.3	Research RAPS-92
26 June	591	1.9	Research RAPS-92
27 June	592	1.7	Ferry GXY - RAP

Total flight hours: 18.5

Total CSU/test and ferry hours: 6.1

Total RAPS-92 hours: 9.6

performed on a new sensor in the reverse-flow temperature probe as well as the Particle Measuring Systems, Inc., (PMS) Forward Scattering Spectrometer Probe (FSSP).

A newly-installed GPS/Loran navigation system was tested during the deployment and an undesirable property of its firmware identified. Position and other derived data supplied by the unit to the T-28 data acquisition system (DAS) were updated only every 3 s, as compared to 1-s updates received from the GPS unit previously used. While 3-s updates are more than adequate for many users, we have decided to go back to the old unit because 1-s updates are highly desirable for research use. With the help of Science Engineering Associates (SEA), capability to record geometric altitude from the GPS unit will also be made available for use beginning in the summer of 1993.

2.1.2 RAP Program to Develop a Radar Hail Detection Algorithm

The second week of the deployment supported the RAPS-92 radar hail-detection-algorithm development project then underway along the Colorado Front Range. This project support was a cost-recovery operation funded by the Federal Aviation Administration (FAA) through RAP via a Purchase Order from the University Corporation for Atmospheric Research. The role of the T-28 was to penetrate regions of thunderstorms that were suspected of containing hail, based on radar signatures from the NCAR CP-2 and CSU/NSF CHILL multiparameter radars. The scientific objective was to verify the presence of hail as well as provide a detailed characterization of the microphysical properties of all cloud and precipitation particles in these regions.

Flight operations for the second week were directed by radio from the RAP operations room in Boulder. The period of operations in support of the RAPS-92 project was characterized by a high frequency of hailstorms within range of the CP-2 and CHILL radars. Flight operations were conducted in coordination with the radars on 5 out of 7 days during this period. There were successful penetrations of hail-bearing regions on all but one flight. One of the storms was tornadic during the period of T-28 penetrations. On the 24 June flight, a hailstone entered the air intake to the engine oil cooler and caused a crack in the cooler; the cooler had to be replaced before another flight could be made. Data from one RAPS-92 flight will be part of the analysis presented by project coordinator E. A. Brandes at the upcoming 26th International Conference on Radar Meteorology in May 1993.

2.2 <u>Instrumentation Development</u>

Beginning in the spring of 1992 and continuing through the following winter, facility staff worked with Science Engineering Associates to develop an interface between the locally-developed hail spectrometer and the SEA data acquisition system used on the T-28. This interface allows recording of particle images from the hail spectrometer on the DAS. Image recording is required to improve interpretation of data from the spectrometer by allowing unambiguous detection of periods when water streaming from the probe housing causes spurious counts indicating the presence of large particles. The interface was successfully demonstrated in the lab late in 1992. Further refinements are now under way to enhance the capability to view images in real time; this capability is required to expedite ground tests of the spectrometer.

Kathy L. Giori, an electrical engineer at SRI International who is experienced with airborne electric field measurements, has been retained by the facility under a subcontract. She will help develop enhanced understanding of the manner in which precipitation charging of the T-28 influences electric field measurements obtained from its suite of field mills during storm penetrations.

Mike Gibson, an undergraduate student in the SDSMT Electrical Engineering Department, has been cooperating with facility staff in benchtop testing of a new instrument to directly measure mass loading of precipitation particles in clouds. This activity has been supported by the facility as well as by the National Aeronautics and Space Administration (NASA) Space Grant program with the State of South Dakota.

2.3 Data Analysis

A large effort was devoted to reducing and summarizing data obtained during COPS-91 and CaPE, field projects in which the T-28 participated in the summer of 1991. Detailed summaries of T-28 data obtained during these projects were completed, the summary report for COPS-91 in June and the corresponding report for CaPE in September. A similar report covering the 1992 Greeley deployment was completed in January. These reports include general summaries of each flight as well as penetration-by-penetration kinematic, microphysical, and electrical statistics. Tables and appendices list instrumentation characteristics, describe how to interpret the various data, and present the aircraft flight tracks.

Facility personnel worked with Professor Kultegin Aydin of The Pennsylvania State University as he and his student, Tom Walsh, analyzed T-28 foil impactor and 2D-P probe data from COPS-91. Aydin, Walsh, and Dusan Zrnić of the National Severe Storms Laboratory (NSSL) made a presentation on this work in June at the International Geoscience and Remote Sensing Symposium in Houston. It described the suite of multiparameter radar data obtained from the Cimarron radar and the corresponding *in situ* data obtained by the T-28 foil impactor in the same hail cloud region during a storm near Norman, Oklahoma, on 5 June 1991.

V. Chandrasekar and V. Bringi, at Colorado State University, as well as several investigators at SDSMT, analyzed T-28 data obtained on 9 August 1991 during CaPE and compared them to CP-2 multiparameter radar signatures. One T-28 penetration passed directly through a "positive ZDR column," providing valuable *in situ* data for verification of inferences from the radar signature. Two conference papers have already evolved from this investigation. This analysis activity at SDSMT has been supported in part by other funding from NSF.

Three conference papers based on analysis of T-28 and related data from the 1989 North Dakota Thunderstorm Project were prepared. Two of them have been converted to journal manuscripts which are now under review.

Assistance from undergraduate students allowed the conversion of archived T-28 data obtained during past field projects, using a variety of data systems and formats, to a form easily retrievable using current-generation computers. This capability was used to compile summaries of microphysical data from three of the projects (NHRE, CCOPE, and COHMEX) for presentation at the WMO Workshop on Cloud Microphysics and Applications to Global Change in August.

2.4 Aircraft and Equipment Maintenance

Other instrumentation and aircraft system maintenance activities during the period include:

Implementation of filtering of the power supply to the aircraft VOR receiver, which allowed it to function reliably for the first time since 1989. The need for this filtering was discovered during the Greeley deployment.

Re-installation of the long-bladed propeller after replacement of one of its blades. (A crack was found in this blade during operations in Florida in 1991.) The longer blades give enhanced power and performance compared to the shorter-blade backup unit.

Installation of new brakes and wheels.

Repair of one aircraft flap.

Replacement of the oil cooler that was damaged by hail during the research flight on 24 June.

Repair of the ADF radio, which had some problems during 1991.

Replacement of the temperature sensing element in the reverse-flow housing with a new platinum-wire element.

Repair of the NCAR hailstone catcher (undertaken at the Mesoscale and Microscale Meteorology Division at NCAR).

Repair of Williamson foil impactor.

Preliminary investigations into other aircraft platforms that might be suitable for penetrations of convective storm environments have focused on the S-2F. Results of these investigations are summarized in Appendix A.

2.5 Software Developments

Software for processing data from the FSSP has been extensively upgraded. Assistance from Darrel Baumgardner of the Research Aviation Facility (RAF) at NCAR was instrumental in accomplishing this upgrade. A number of studies have shown that the FSSP response will affect the cloud droplet distribution being indicated. A data reduction routine from Baumgardner is used to retrieve the actual cloud droplet distribution from the measured distribution. The effect of the FSSP on the actual distribution can be characterized by a response matrix which accounts for the optical (non-uniform laser beam intensity cross-section) and electronic (electronic response times) properties of the probe. This routine uses Markowski's modification to Twomey's aerosol data inversion algorithm to calculate the response matrix and the actual distribution. An example of this is shown in Fig. 1, where the increasing channel number corresponds to increasing droplet size. The measured distribution is plotted as a solid line with circles and the estimate of the actual distribution as a dashed line with asterisks (*).

Better estimates of cloud droplet population statistics are obtained from this routine. In addition to the calculation of the actual distribution, the FSSP sampling volume must be modified to account for dead-time and edge-effect losses. The corrected sampling volume and the calculated actual distribution are used to compute the droplet concentration and liquid water concentration (LWC). These calculations are incorporated in the front-end software to the routines from Baumgardner.

Generally better agreement between FSSP and Johnson-Williams (JW) hot wire LWC values is obtained when Baumgardner's routine is used. Figure 2 is a plot of LWC against time for 3 minutes of T-28 Flight 590 on 24 June 1992. The Johnson-Williams hot wire LWC is plotted as a solid line, the FSSP LWC before the correction routine is applied as asterisks (*), and FSSP LWC after correction as circles with the dashed line.

The T-28 data-analysis software has been upgraded to provide more informative presentations, both for rapid analysis in the field and for more detailed analyses subsequent to field operations. The improvements facilitate use by student research assistants with minimal experience in aircraft data analysis.

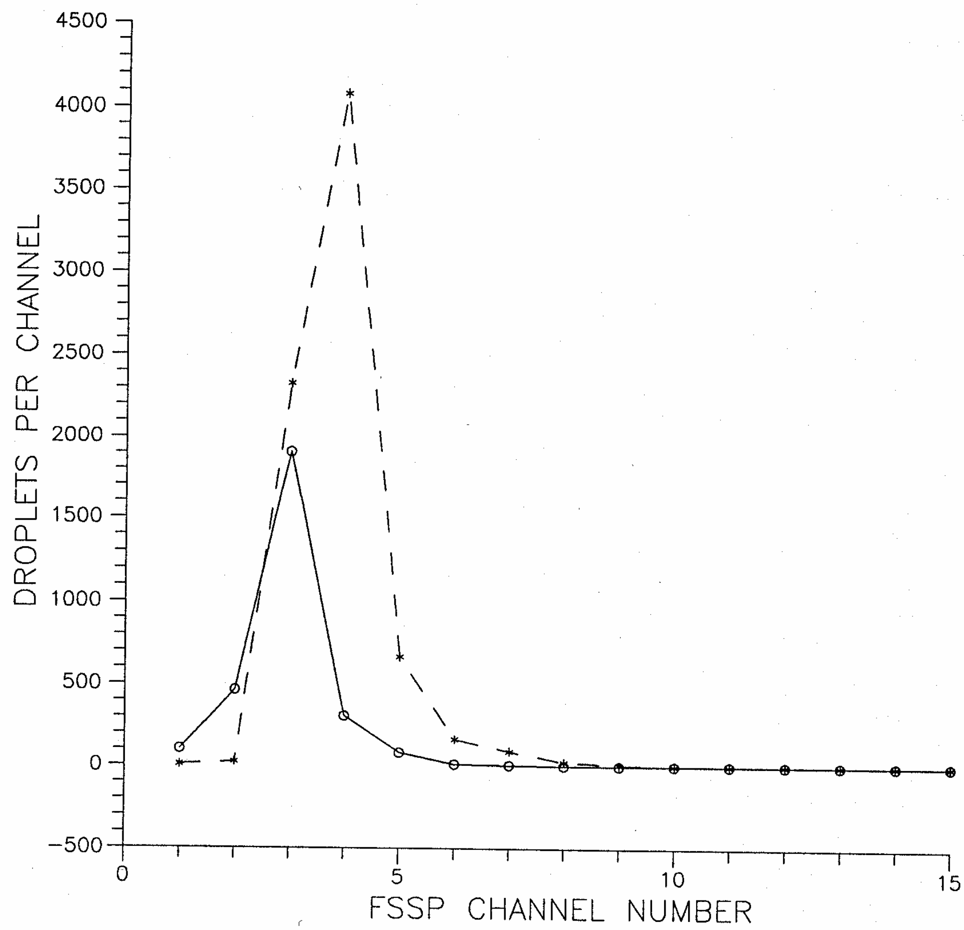

Fig. 1: Number of droplets per channel as a function of FSSP channel number (channel number is related to droplet diameter) for distribution at time 153954 of T-28 Flight 590 on 24 June 1992. Solid line with circles is measured distribution and dashed line with asterisks is estimate of actual distribution from correction routine.

2.6 Data Exchanges and Information Requests

T-28 data obtained during the Colorado flight operations in 1992 have been translated into a format compatible with software in-house at the RAP group at NCAR. These data have been transferred over the INTERNET to their computer systems.

Extensive exchange and cooperative analysis of T-28 observations obtained during CaPE (Convection and Precipitation/Electrification project,

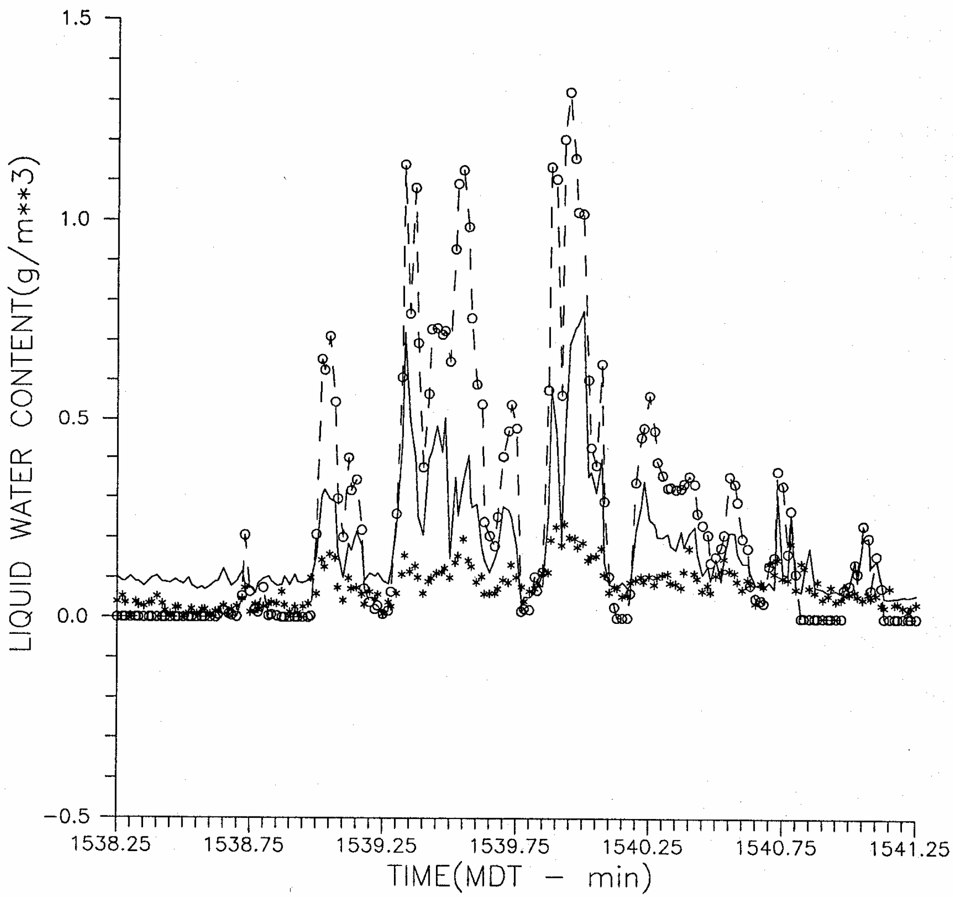

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Fig. 2: Liquid Water Concentration (LWC) as a function of time for a portion of T-28 Flight 590 on 24 June 1992. The solid line is the J-W LWC; asterisk (*) indicates the FSSP LWC before correction; and the dashed line with circles indicates the FSSP LWC after correction. Each time tic is 3 sec.

summer, 1991) has been undertaken with the research group headed by V. N. Bringi in the Electrical Engineering Department at CSU. Data from the T-28 flight on 15 August 1991, during CaPE, have been supplied to Ms. Sandra Yuter at the University of Washington. Other general information on CaPE T-28 activities has been supplied to the research group of Peter Ray at Florida State University, and to Earle Williams at the Massachusetts Institute of Technology.

Further analysis assistance has been extended to the research group headed by K. Aydin at The Pennsylvania State University. They have been studying measurements obtained during several penetrations by the T-28 in storms being scanned by the NOAA NSSL multiparameter Cimarron radar during COPS-91.

Turbulence and related T-28 data from the COPS-91 profiler overflight of 11 June 1991 were transmitted to R. Doviak of the National Severe Storms Laboratory. Dr. Doviak continues to work with the facility staff on the processing and interpretation of the aircraft turbulence data.

Data from the 27 June 1989 T-28 flight during the North Dakota Thunderstorm Project have been supplied to Rodger Brown at NSSL.

Aircraft performance characteristics were transmitted to W. Woodley for use in calculations related to the possibility of generating Aircraft Produced Ice Particles (APIPs). Reprints summarizing T-28 observations from some past projects were sent to Professor Alan Blyth at the New Mexico Institute of Mining and Technology. Software for producing hard-copy output from 2D-probe images was transmitted to R. Czys at the Illinois State Water Survey.

General information concerning T-28 facility capabilities has been supplied to:

William Woodley, of Woodley Weather Consultants

Felix Pitts, NASA Langley Research Center

Lawrence Walko, U.S. Air Force Aero Propulsion Directorate

Rosemarie McDowall, Galaxy Scientific Corporation

Michael Glynn, FAA

Lana Hoff, editor of the CSU College of Engineering Engineering Review

Paul Bertorelli, IFR Magazine

In addition, informational items about the T-28 appeared in the 27 June issue of the Greeley (CO) Tribune and the Summer issue of Wings West.

2.7 Educational Activities

The following SDSMT graduate students were involved in the analysis of T-28 and related data from CaPE and other field projects:

L. Chen

J. French

R. Ramachandran

Mr. Ramachandran attended the NCAR Summer Colloquium on Observational Techniques in the Atmospheric Sciences.

The following undergraduate students have been assisting with instrument development or the reduction and organization of T-28 data:

M. Gibson

G. Priegnitz

N. Schwab

In addition, students from the CSU/CHILL REU group visited the T-28 while it was at Greeley (see Sec 2.1), and some are working with the T-28 data from that project as well as from CaPE.

2.8 Travel

The following travel in support of facility activities was accomplished during the year:

P. L. Smith to Boulder on 26-28 February to attend RAF Fleet Workshop.

J. E. Leigh to Minneapolis on 25-27 March to return T-28 propeller.

P. L. Smith to visit NSF offices in Washington, DC on 24 and 27 March.

R. F. Kelley to Minneapolis on 25-27 March to consult with Minco on temperature sensor system for T-28.

R. F. Kelley to Boulder and Fort Collins on 5-9 April to confer with NCAR staff about FSSP and visit with CSU Atmospheric Science staff.

P. L. Smith to Boulder on 3-8 April to attend OFAP/FAC panel meetings.

A. G. Detwiler and P. L. Smith to Denver on 13-15 May to attend North Dakota Tracer Experiment planning meeting and Weather Modification Association Annual Meeting.

D. P. Custis to Bismarck on 2-5 and 9 June for avionics maintenance on T-28.

A. G. Detwiler, D. P. Custis, J. E. Leigh, G. N. Johnson, K. R. Hartman, and R. F. Kelley to Greeley on 14-27 June to participate in T-28 field project.

C. A. Summers to Greeley on 16-17 June to visit T-28 field project.

P. L. Smith to Greeley on 17-22 June to visit T-28 field project.

D. P. Custis to Boise and Chico on 26-27 July to research aircraft modification and explore replacement aircraft for T-28.

P. L. Smith to Toronto on 8-15 August to attend WMO Workshop on Cloud Microphysics and Application to Global Change and present a paper.

P. L. Smith and A. G. Detwiler to Montreal on 15-21 August to attend 11th International Conference on Clouds and Precipitation and present papers.

A. G. Detwiler to Salt Lake City on 23-28 August to attend 13th International Conference on Nucleation and Atmospheric Aerosols and present a paper.

P. L. Smith to Boulder on 5-9 October to attend fall OFAP/FAC panel meetings and NCAR Remote Sensing Workshop.

R. F. Kelley to Boulder on 7-9 October to attend NCAR Remote Sensing Workshop.

D. P. Custis to Atlantic City on 2-13 October to attend 1992 International Aerospace and Ground Conference on Lightning and Static Electricity.

D. P. Custis and C. A. Summers to San Diego 30 October - 5 November to attend T-28 ground school.

3. FUTURE PLANS

3.1 Field Projects to be Supported During the Next Year

The T-28 will be participating in the North Dakota Tracer Experiment (NDTE), operating from Bismarck, North Dakota, for the period 21 June through 30 July 1993. Its role will be to participate in the detection of gaseous tracers and provide microphysical measurements in central regions of convective storms to support investigation of transport and dispersion, ice initiation, and hail growth processes in High Plains clouds. Support for T-28 operations will come from the Federal/State Cooperative Program in Atmospheric Modification Research (AMP) operated by the National Oceanic and Atmospheric Administration and six states, including the State of North Dakota.

Some discussions have been held regarding possible support of the RAPS-93 project, but no formal request has been received. An inquiry was also received about support of a possible Texas project in August 1993, but that project has been postponed to 1994.

3.2 Data Analysis

Data analysis work will continue through the year, with emphasis on the data from CaPE. Reduction and analysis of data to be collected during the NDTE will begin following the summer 1993 project.

3.3 Facility Development Activities

Preparation of a 5th electric-field-mill mounting location will be completed. The facility engineer plans further development of spray testing equipment and electronic pattern generators for field testing of particle probes. Further upgrades to aircraft avionics will be made as funding permits.

Plans call for development of processing and analysis software for manipulation of T-28 data on work stations operating in the UNIX environment. Machines of this class are becoming the standard computer platform for atmospheric scientists. Software already developed at NCAR and other institutions will be utilized as much as possible.

Efforts are under way to acquire a second T-28 as a source for replacement parts. It is currently anticipated that after the summer 1993 fire season, the State of Alaska will be surplusing a number of T-28's they have been using for fire spotting and support of slurry bombing operations.

3.4 Future Field Projects

The T-28 has capabilities suitable for participation in the following projects currently under discussion for 1994 or 1995:

A spring tornado/atmospheric electricity project based at NSSL.

A rain enhancement research project in western Texas, as part of the AMP.

A contemplated rain enhancement research project in Illinois, also part of the AMP.

The U.S. Weather Research Program.

Future field seasons of the RAP radar hail detection algorithm development program.

Facility staff will work with the various project planners to determine any appropriate role for T-28 flight support.

4. PERSONNEL

Charles A. Summers has been hired as a backup pilot. He will participate in the NDTE this summer along with our primary pilot, Dan Custis.

Dr. Richard F. Kelley's work as a post-doctoral scientist with the T-28 facility will continue through about half of the next year of facility operation.

5. PUBLICATION ACTIVITY

Several publications involving work conducted under the T-28 facility cooperative agreement appeared during the year, and more are in progress. They are listed below, with indications of other sources of support where appropriate.

<u>Published in Refereed Journals</u>:

Boe, B. A., J. L. Stith, P. L. Smith, J. H. Hirsch, J. H. Helsdon, A. G. Detwiler, H. D. Orville, B. E. Martner, R. F. Reinking, R. J. Meitin and R. A. Brown, 1992: The North Dakota Thunderstorm Project -- A cooperative study of High Plains thunderstorms. *Bull. Amer. Meteor. Soc.*, **73**, 145-160. (Supported mainly by the North Dakota Federal/State Cooperative Program and other NSF grants.)

<u>Submitted to Refereed Journals</u>:

Detwiler, A. G., N. C. Knight and A. J. Heymsfield, 1993: Magnitude of error factors in estimating of snow particle masses from images. *J. Appl. Meteor.*, **32**. [In press] (Jointly supported by the National Center for Atmospheric Research.)

Detwiler, A. G., P. L. Smith, J. L. Stith and D. W. Burrows, 1993a: Ice-producing processes in a North Dakota cumulus cloud. [Submitted to *Atmos. Res.*] (Jointly supported by another NSF grant and the North Dakota Federal/State Cooperative Program.)

Detwiler, A. G., P. L. Smith, J. L. Stith and D. W. Burrows, 1993b: Observations of microphysical evolution in a High Plains thunderstorm anvil. [Submitted to *Atmos. Res.*] (Jointly supported by another NSF grant and the North Dakota Federal/State Cooperative Program.)

<u>Conference Presentations</u>:

Detwiler, A. G., P. L. Smith and J. L. Stith, 1992: Ice-producing processes in North Dakota clouds. *Proc. 13th Intnl. Conf. on Nucleation and Atmospheric Aerosols,* Salt Lake City, Utah, 305-308. (Jointly supported by another NSF grant and the North Dakota Federal/State Cooperative Program.)

Detwiler, A. G., P. L. Smith and J. L. Stith, 1992: Observations of microphysical evolution in a High Plains thunderstorm. Preprints, *11th Intnl. Conf. on Clouds and Precipitation,* Montreal, Quebec, Canada, **Vol. 1**, 260-263. (Jointly supported by another NSF grant and the North Dakota Federal/State Cooperative Program.)

Smith, P. L., A. G. Detwiler, D. J. Musil, V. Chandrasekar and V. N. Bringi, 1992: Coordinated aircraft and multi-parameter radar observations of CaPE warm-based clouds. Preprints, *11th Intnl. Conf. on Clouds and Precipitation,* Montreal, Quebec, Canada, **Vol. 1**, 444-446. (Jointly supported by other NSF grants.)

Smith, P. L., and A. G. Detwiler, 1992: Geographic variation of mature storm microphysics and dynamics. Presented at the WMO Workshop on Cloud Microphysics and Applications to Global Change, Toronto, Ontario, 10-14 August.

Bringi, V. N., A. G. Detwiler, V. Chandrasekar, P. L. Smith, L. Liu, I. J. Caylor and D. J. Musil, 1993: Multiparameter radar and aircraft study of the transition from early to mature storm during CaPE: The case of 9 August 1991. To be presented at the *26th Intnl. Conf. on Radar Meteorology,* 24-28 May, Norman, OK, Amer. Meteor. Soc. (Jointly supported by another NSF grant and the North Dakota Federal/State Cooperative Program.)

Musil, D. J., A. G. Detwiler, D. L. Priegnitz, M. R. Hjelmfelt and P. L. Smith, 1993: Radar and aircraft investigation of a North Dakota Thunderstorm Project storm complex (10 July 1989). To be presented at the *26th Intnl. Conf. on Radar Meteorology,* 24-28 May, Norman, OK, Amer. Meteor. Soc. (Jointly supported by another NSF grant and the North Dakota Federal/State Cooperative Program.)

<u>Reports</u>:

Detwiler, A. G., and P. L. Smith, 1992: T-28 participation in the Cooperative Oklahoma Profiler Studies (COPS-91). Report SDSMT/IAS/R-92/03, Institute of Atmospheric Sciences, South Dakota School of Mines and Technology, Rapid City, SD. 27 pp + app.

Detwiler, A. G., and P. L. Smith, 1992: T-28 participation in the Convection and Precipitation/Electrification (CaPE) experiment. Report SDSMT/IAS/R-92/04, Institute of Atmospheric Sciences, South Dakota School of Mines and Technology, Rapid City, SD. 32 pp + app.

Detwiler, A. G., R. F. Kelley and P. L. Smith, 1993: Summary report of T-28 deployment to Colorado (June 1992). Report SDSMT/IAS/R-92/09, Institute of Atmospheric Sciences, South Dakota School of Mines and Technology, Rapid City, SD. 33 pp. + app.

Other Items:

Detwiler, A. G., and P. L. Smith, 1992: Armored T-28 enters 23rd year of storm research. *ATD Observer*, Winter 1992, p. 11.

6. BUDGET INFORMATION

Third Year (Revised)

(SEE INSTRUCTIONS ON REVERSE BEFORE COMPLETING

SUMMARY PROPOSAL BUDGET

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (MONTHS) Proposed	Granted
AWARD NO.		

ORGANIZATION Institute of Atmospheric Sciences
South Dakota School of Mines and Technology

PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR
Paul L. Smith

A. SENIOR PERSONNEL: PI/PD. Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.6. show number in brackets)	NSF Funded Person-mos. CAL.	ACAD	SUMR	Funds Requested By Proposer	Funds Granted By NSF (If Different)
1. P. L. Smith - PI (0.40 month, cost-share)	1.60			$ 13,304	$
2. A. G. Detwiler-Facility Scientist (9.0 mo. cost-share)	0			0	
3.					
4.					
5. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)					
6. (2) TOTAL SENIOR PERSONNEL (1-5)	1.60			13,304	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (1) POST DOCTORAL ASSOCIATES	5.40			17,785	
2. (4) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	25.82			98,587	
3. ( ) GRADUATE STUDENTS					
4. ( ) UNDERGRADUATE STUDENTS					
5. (1) SECRETARIAL CLERICAL				3,510	
6. ( ) OTHER					
TOTAL SALARIES AND WAGES (A+B)				133,186	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				25,305	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A+B+C)				158,491	
D. PERMANENT EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $1,000:) 2 - FM Radios = $1,500; Attitude Indicator = $1,400; Cellular Phone = $400; Computer Upgrade = $1,670; Field Printer (InkJet, Color) = $500					
TOTAL PERMANENT EQUIPMENT				5,470	
E. TRAVEL 1. DOMESTIC (INCL. CANADA AND U.S. POSSESSIONS)				9,777	
2. FOREIGN				0	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ 2. TRAVEL 3. SUBSISTENCE 4. OTHER					
( ) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				8,083	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				3,634	
3. CONSULTANT SERVICES				0	
4. COMPUTER (ADPE) SERVICES				0	
5. SUBCONTRACTS				0	
6. OTHER				17,079	
TOTAL OTHER DIRECT COSTS				28,796	
H. TOTAL DIRECT COSTS (A THROUGH G)				202,534	
I. INDIRECT COSTS (SPECIFY RATE AND BASE) @ 43.5% of total Salaries and Wages					
TOTAL INDIRECT COSTS				57,936	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				260,470	
K. COST-RECOVERY FUNDS				5,470	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$255,000	$

PI/PD TYPED NAME & SIGNATURE*	DATE	FOR NSF USE ONLY		
Paul L. Smith *Paul L. Smith*	*12 Mar 93*	INDIRECT COST RATE VERIFICATION		
INST. REP. TYPED NAME & SIGNATURE*	DATE	Date Checked	Date of Rate Sheet	Initials-DGC
Timothy G. Henderson *Sharon L Reid for:*	*17 Mar 1993*			

NSF Form 1030 (8/90) *Supersedes All Previous Editions*

*SIGNATURES REQUIRED ONLY FOR REVISED BUDGET (GPM 233)

BUDGET EXPLANATION PAGE

Third Year: 15 May 1993-14 May 1994

	COLLEGE FY	EFFORT MONTHS	MONTHLY SALARY*	REQUESTED FUNDS	COST SHARING MAN-MO	COST SHARING FUNDS
A. SENIOR PERSONNEL:						
1. Facility Manager						
P.L. Smith	1993	0.20	8,034	1,607	0.05	$371
	1994	1.40	8,355	11,697	0.35	$2,699
2. Facility Scientist						
A.G. Detwiler	1993	0.00	4,882	0	1.25	$5,750
	1994	0.00	5,077	0	7.75	$37,076
Subtotal				13,304		$45,896
B. OTHER PERSONNEL:						
2. Other Professionals						
a. Research Engineer						
G.N. Johnson	1993	0.75	5,298	3,974		
	1994	5.00	5,510	27,550		
b. Programmer						
K.R. Hartman	1993	0.75	3,146	2,360		
	1994	5.00	3,272	16,360		
c. Research Pilot						
	1993	0.40	5,325	2,130		
	1994	2.60	5,538	14,399		
d. Aircraft Mechanic						
J.E. Leigh	1993	1.50	2,682	4,023		
	1994	9.82	2,830	27,791		
e. Postdoctoral scientist						
R.F. Kelley	1993	1.50	3,201	4,802		
	1994	3.90	3,329	12,983		
5. Secretarial	1993	0.30	1,677	503		
	1994	1.70	1,769	3,007		
Subtotal				119,882		
TOTAL SALARIES AND WAGES:				133,186		$45,896
C. FRINGE BENEFITS:						
1. Staff @ 19.0% of Salaries and Wages				25,305		8,720
TOTAL SALARIES, WAGES, AND BENEFITS:				158,491		$54,616
D. PERMANENT EQUIPMENT:						
a. FM radios(2)				1,500		
b. Attitude indicator				1,400		
c. Cellular phone				400		
d. Computer upgrade				1,670		
e. Field Printer(InkJet, Color)				500		
				5,470		

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*Salaries include a vacation accrual ajustment

E. TRAVEL:		
1. Domestic		
a. Travel to panel meetings, project planning meetings and scientific conferences	7,183	
b. Local mileage for required travel between campus and airport(T-28 location)	2,594	
Subtotal	9,777	
2. Foreign		
none	0	
Subtotal	0	
G. OTHER DIRECT COSTS:		
1. Materials and Supplies		
a. Miscellaneous small parts and repairs to support operation of T-28 and instrumentation system	4,400	
b. Fuel/oil for T-28 test flights(16 hrs @ $122/hr)	1,952	
c. Fuel oil for heating hanger(600 gal @ $1.50/gal)	900	
d. Miscellaneous supplies	500	
e. Miscellaneous reproduction	331	
Subtotal	8,083	
2. Publication costs		
a. Journal paper(2)	3,220	
b. Conference paper	414	
Subtotal	3,634	
4. Computer (ADPE) Services		
a. Local Pc's, etc, provided	0	
Subtotal	0	
5. Subcontract: None	0	
6. Others		
a. Propeller inspection	1,000	
b. Rental of hangar/shop facility	5,358	
c. Utilities and trash	1,111	
d. Telephone service for hangar/shop,	529	
e. Liability coverage on T-28	2,600	
f. Annual subscriptions	953	
g. Maintenance and repair services that are beyond in-house capability	4,400	
h. Long distance telephone calls	600	
i. Registration fee and misc. services	528	
Subtotal	17,079	
H. TOTAL DIRECT COSTS:	$202,534	$54,616
I. INDIRECT COSTS: On campus rate @ 43.5% of total salaries and wages	$57,936	$19,965
J. TOTAL COSTS:	$260,470	$74,581
K. Residual Funds	$5,470	
L. AMOUNT OF THIS REQUEST:	$255,000	

7. CURRENT AND PENDING SUPPORT

7.1 Paul L. Smith, Facility Manager

A. Current Support:

1) Supporting Agency: North Dakota Atmospheric Resource Board
   Project Title: Continued Analysis of Data for the North Dakota Thunderstorm Project
   Award: $115,000
   Period of Award: 1 May 1992-31 August 1993
   Commitment: 9.2% per year
   Location: Rapid City, South Dakota

2) Supporting Agency: National Science Foundation
   Project Title: Armored T-28 Aircraft Facility for Research Requiring Storm Penetrations
   Award: $250,000
   Period of Award: 15 may 1992-14 May 1993
   Commitment: 12.9% per year
   Location: Rapid City, South Dakota

3) Supporting Agency: North Dakota Atmospheric Resource Board
   Project Title: Continued Analysis of Data for the North Dakota Thunderstorm Project and Planning for the North Dakota Tracer Experiment
   Award: $125,000
   Period of Award: 15 February 1993 - 31 August 1994
   Commitment: 10.4% per year
   Location: Rapid City, South Dakota

4) Supporting Agency: National Aeronautics and Space Administration
   Project Title: Continued Investigation of Satellite Area-Time-Integral Techniques for Rainfall Estimation
   Award: $60,000
   Period of Award: 1 May 1992-30 April 1993
   Commitment: 4.2 % per year
   Location: Rapid City, South Dakota

5) Supporting Agency: National Aeronautics and Space Administration
Project Title: National Space Grant College and Fellowship Program
Award: $660,000
Period of Award: 1 March 1991-28 February 1995
Commitment: 20.0% per year
Location: Rapid City, South Dakota

6) Supporting Agency: National Science Foundation
Project Title: Investigation of Cloud Microphysical, Kinematic and Electrical Characteristics
Award: $227,995
Period of Award: 1 August 1991-31 June 1994
Commitment: 15.0% per year
Location: Rapid City, South Dakota

B. Pending Support:

1) Supporting Agency: National Science Foundation
Project Title: Investigation of Convective Cloud Processes as Part of the North Dakota Tracer Experiment
Amount Requested: $342,500
Period of Request: 1 March 1993-28 February 1996
Commitment: 15.0% first year
Location: Rapid City, South Dakota

2) Supporting Agency: National Science Foundation
Project Title: Computer Upgrade for the Analysis of Weather Data
Amount Requested: $20,000
Period of Request: 1 January 1993-31 December 1993
Commitment: 0.0%
Location: Rapid City, South Dakota

3) Supporting Agency: National Science Foundation
Project Title: Armored T-28 Aircraft Facility for Research Requiring Storm Penetrations
Amount Requested: $255,000
Period of Request: 15 May 1993-14 May 1994
Commitment: 13.3% per year
Location: Rapid City, South Dakota

7.2 Andrew G. Detwiler, Facility Scientist

A. Current Support:

None (9 month cost-sharing by State of South Dakota as part of NSF T-28 Facility Grant).

B. Pending Support:

1) Supporting Agency: U. S. Environmental Protection Agency
Project Title: Effect of Turbulence and Aerosol Size Distribution on PM-10 Sampling Efficiency
Amount Requested: $214,510
Period of Request: 1 July 1993-30 June 1996
Commitment: 8.3% per year
Location: Rapid City, South Dakota

8. COST SHARING FUNDS

a) In the second year of this agreement, SDSMT has provided a total of $55,396 in cost-sharing through 28 February 1993; $34,862 in salaries; $5,434 in benefits, and $15,100 in indirect costs. In the period 1 March - 15 May 1993, we expect to provide an additional $12,031 in cost-sharing; $7,560 in salaries, $1,183 in benefits, and $3,288 in indirect costs. The total estimated cost-sharing for the second year is thus $67,427. The effort cost-shared has been .435 months for P. L. Smith and 6.93 months for A. G. Detwiler through 28 Feb 1993; we anticipate an additional 0.12 months for P. L. Smith and 2.30 months for A. G. Detwiler for the period 1 March-15 May 1993. Thus, the cost-sharing totals of 0.45 months for P. L. Smith and 9.0 months for A. G. Detwiler for year two of the agreement will have been slightly exceeded.

b) The SDSMT will be providing a total of $74,581 in estimated cost-sharing for the third year. (See detailed budget in Section 6.) These funds provide 0.40 months cost-sharing effort for P. L. Smith and 9.00 months for A. G. Detwiler plus associated fringe benefits and indirect costs for year three of the agreement.

9. ESTIMATE OF RESIDUAL FUNDS AS OF 15 MAY 1993

The current estimate is that all of the allocated base funds will have been expended by the end of the current project year (14 May 1993). Residual operational (deployment) funds of $850 are anticipated to remain unexpended as of 14 May.

10. COST RECOVERY FUNDS

a) Cost recovery funds totaling $5,470 were collected in connection with the support of the RAPS-92 project during June 1992. The budget estimate includes a request to use those funds for permanent equipment to upgrade the facility capabilities.

b) For the coming year, we do not, at present, anticipate the generation of any cost-recovery funds. No requests have been received for the support of any non-NSF-funded projects during the summer of 1993.

11. REPLACEMENT AND UPGRADE EQUIPMENT PURCHASED UNDER COOPERATIVE AGREEMENT

Mast and motorized antenna rotator for telemetry antenna	$ 136
Electronic dipstick kit	$ 325
Replacement parachute	$ 964
Replacement battery for T-28	$ 318
Replacement oil cooler (to replace the one damaged in a hailstorm during the Greeley deployment)	$ 306
Replacement power supply for hail spectrometer	$ 235
80386 motherboard and 80387 math coprocessor for a personal computer used for data reduction	$ 400
Software upgrade and hail spectrometer interface card for data systems	$4,000

12. REFERENCES

Detwiler, A. G., Richard F. Kelley and Paul L. Smith, 1992. Summary Report of T-28 Deployment to Colorado (June, 1992). SDSMT/IAS/R-92/09. [Available from Institute of Atmospheric Sciences, South Dakota School of Mines and Technology, Rapid City, SD 57701-3995]

APPENDIX A

Potential T-28 Replacement Aircraft

After more than 20 years of mature storm research, the SDSMT armored T-28 is still performing its mission. Recent equipment additions, such as a Global Positioning Satellite (GPS) navigation system, a new computer-based data acquisition system, additional electric field mills, an improved air-to-ground telemetry system, and an improved voice recorder enhance its capabilities. Utilization of a SF_6 detector in tracer experiments has also extended the value of the facility.

However, there are significant limitations associated with this airframe. They are:

1. Heavy pilot workload.
2. Lack of airframe deicing.
3. Limited on-station time.
4. Limited range.
5. Daytime operations only.
6. Limited payload capability.
7. Limited altitude capability.

Recognizing the above limitations, the facility staff has been engaged in preliminary research to identify a suitable, more capable replacement aircraft.

Our initial considerations did not include turbine-powered aircraft for the following reasons:

1. Higher air speeds would require excessive armoring against hail impact.

2. Turbine engines are prone to severe damage from both hail ingestion and lightning strikes.

3. Engine screens or deflectors, while capable of providing protection from hail, are likely to ice over, resulting in engine flame outs.

Our research has focused on the Navy Grumman S-2F or its passenger/cargo sister, the C-1A, as a possible replacement. This twin-engine anti-submarine aircraft is now surplus and readily available. It is powered by a more powerful (1525 HP each) version of the Wright 1820 engine that has performed so well on the T-28. For the past 10-15 years, it has been utilized as a fire bomber by the California Forest Service.

Some suggested modifications to this aircraft would include:

1. Replace the rear engine case with an 86 series engine to provide a 2-stage supercharger. This will permit working altitudes in the 25,000 to 30,000 foot range. (Estimated cost - $20,000)

2. Install a weeping-wing de-ice system for all weather (including winter) operations. (Estimated cost - $45,000)

3. Provide stainless steel wing and horizontal tail straps to permit higher stress (G-force) loading. This type of modification is presently utilized on Beech King Airs. (Estimated cost - $100,000)

Armoring up to T-28 standards along with inspections and maintenance to restore an S-2F to airworthy conditions would be required, at a cost to be determined. It would take approximately $15,000 to transfer the existing instrumentation and data acquisition equipment from the T-28 to the S-2F.

This program would provide a research vehicle that has the following advantages over the existing T-28:

1. 3,000 to 4,000 pound payload.
2. Radar capability (with a beefed-up radome).
3. Up to 4 crew members.
4. Night flight capability.
5. 4.5 hours endurance.
6. Worldwide ferry capability with a 500-gallon bladder tank in the fuselage.
7. Bomb bay and nacelle release capability.
8. Six external pylons.
9. Winter storm research capability.

If there is interest in this possibility, a study should be accomplished to identify an appropriate airframe and to verify the projected figures. Aero Union in Chico, CA, has extensive experience in this type of activity and could be asked to participate in the study.