Report SDSMT/IAS/R-88/01 February 1988

ANNUAL PROGRESS REPORT ON T-28 AIRCRAFT FACILITY COOPERATIVE AGREEMENT (ATM-8620145)

By: Andrew G. Detwiler and Paul L. Smith

Prepared for:

Experimental Meteorology Program
National Science Foundation
1800 G Street, N.W.
Washington, DC 20550

Cooperative Agreement No. ATM-8620145

Institute of Atmospheric Sciences

South Dakota School of Mines and Technology

Rapid City, South Dakota 57701-3995

ABSTRACT

This is the annual progress report required under the terms of Cooperative Agreement No. ATM-8620145 between the National Science Foundation (NSF) and the South Dakota School of Mines and Technology (SDSM&T). This agreement provides for operation of the SDSM&T armored T-28 meteorological research aircraft as a national facility for investigations into cloud, thunderstorm, and hailstorm processes. This report covers the period 1 April 1987-15 February 1988, during which the T-28 was operated for the first time in the facility mode in support of a research project in North Dakota.

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1. INTRODUCTION

The T-28 closed out 1987 hangared at Rapid City Regional Airport, stripped of its research equipment and undergoing surgery to remove the wire bundles originally placed in its wings nearly 20 years ago when the aircraft was modified from a military trainer to an atmospheric research platform. Its major research activity for the year was participation in a summer project in western North Dakota during which coordinated penetrations of small to medium-size cumulus congestus and small thunderstorms were carried out. The goal of the experiment was to understand transport and dispersion processes in these clouds, and to use this information to develop more effective precipitation modification techniques. The T-28 and University of North Dakota Citation penetrated clouds with sophisticated cloud physics and tracer gas detecting gear while a third aircraft released silver iodide and a tracer gas simultaneously into the cloud.

Several good case studies are underway at the moment based on data from the North Dakota project. Several more generic cloud physics studies based on composited cloud data sets are also beginning. In one study, T-28 and Citation microphysical data are being used to compute cloud optical properties for comparison to properties observed in LANDSAT multi-spectral scanner imagery. T-28 data from North Dakota form part of the basis for a paper discussing mixing in clouds to be presented this summer at the International Cloud Physics Conference (Stith et al., 1988).

This report summarizes T-28 facility activity over the period 1 April 1987-15 February 1988. More detailed information concerning activities within the most recent quarter will be given in the appropriate sections since these activities have not been covered in previous quarterly reports.

2. PROGRESS DURING THE YEAR

2.1 T-28 Participation in Field Projects During 1987

Early in 1987, there was interest in having the T-28 participate in two field projects. Both were connected with the NOAA Federal/State Cooperative Program. A field project in Dickinson, North Dakota, had the goal to investigate transport, dispersion, mixing, and artificially-stimulated ice nucleation in clouds ranging in size from cumulus congestus to small cumulonimbus. A planned field project in east central Illinois (Precipitation Augmentation for Crops Experiment, or PACE) had interest in following the development of large precipitation particles in large convective clouds, with the goal being to better forecast and modify this precipitation development.

The Illinois project was delayed until 1988, but the North Dakota project was carried out during the period 7 June-5 July. Eleven equipment test and research flights were carried out during the period (Table 1). T-28 data tapes from the project have been shipped to the major participants. The data collected are now being used for several studies that promise to provide a clearer picture of transport and mixing processes in convective clouds. A paper discussing preliminary results of the North Dakota work is to be presented at this summer's International Cloud Physics Conference (Stith et al., 1988).

The principal experimental technique involved the use of a tracer gas (sulfur hexafluoride) to tag air parcels treated by the seeding aircraft (Stith et al., 1986; Stith and Benner, 1987). This approach permits combined studies of transport and dispersion processes inside the clouds; entrainment and mixing processes; and the nucleating characteristics of the seeding agents. For these experiments, the T-28 was equipped with a SF_6 analyzer of the type described by Stith and Benner (1987). That required removal of the T-28 primary MicroNOVA data acquisition system, to make payload and space available for the analyzer. This change, in turn, required some rearrangement of the data channels on the Particle Measuring Systems (PMS) Data Acquisition System (furnished by NCAR); that system continued to give problems because of its advancing age. A paper discussing preliminary results of the North Dakota work is to be presented at this summer's International Cloud Physics Conference (Stith et al., 1988).

A novel technique for tracing the development of hail particles in cumulonimbus clouds (Knight et al., 1986) was also tested. Due to lack of adequate real-time aircraft tracking capabilities until late in the project, only one cumulonimbus was penetrated during the season. The intent was to release iron powder in the feeder cloud region of the storm with one aircraft, and to capture hailstones (hopefully containing some iron particles that might allow one to diagnose precipitation growth processes and trajectories) in another region with the T-28 or on the ground beneath the storm. The attempt failed when the pyrotechnic powder release procedure malfunctioned.

TABLE 1

1987 Flight Summary

Date	Flight No.	Hours	Remarks
04/22	462	1.8	RAP → WATERTOWN
	463	1.3	WATERTOWN → MSP
04/25	464	1.4	MSP → WATERTOWN
	465	1.8	WATERTOWN → RAP
05/18	466	1.9	RAP → ROCK SPRINGS
	467	1.4	ROCK SPRINGS → SLC for VOR repair and SF_6 instrument installation
05/26	468	1.7	SLC → CASPER
	469	1.0	CASPER → RAP
06/07	470	1.4	Ferry to DIK
06/09	471	1.3	In-trail test
06/13	472	1.8	Sniffer test
06/14	473	1.3	Sniffer test
06/16	474	2.1	Research
06/18	475	2.0	Research
06/19	476	1.9	Ground release of SF_6
06/22	477	2.0	Tower fly-by
	478	1.0	LANDSAT "ground truth"
06/28	479	1.7	Research
06/29	480	1.9	Research
07/04	481	2.0	Research
07/05	482	1.1	Ferry home to RAP
09/18	483	1.9	RAP → GOODLAND, KAN
09/19	484	2.2	GOODLAND → LUBBOCK
	485	1.1	LUBBOCK → COLEMAN (paint job)
10/01	486	0.5	COLEMAN → ABILENE
	487	2.0	ABILENE → LIBERTY
10/02	488	2.0	LIBERTY → SIDNEY, NE
	489	1.2	SIDNEY → RAP
	TOTAL HOURS	44.7	

2.2 Summary of Flight Activity During 1987

Table 1 summarizes all of the flight activities of the T-28 during 1987. The aircraft was flown to Minneapolis in April for a mandatory propeller inspection. A trip to Salt Lake City in May was made for repair of the VOR and a preliminary fit of sulfur hexafluoride instrumentation by North American Weather Consultants (for use in the North Dakota field program). Flights 470 to 482 covered the field project activity in June and early July. The last seven flights were part of a trip to Coleman, Texas, for a new paint job.

It was a relatively light year for the aircraft due to the delay of the proposed PACE field program until 1988. Flight hours for 1987 totalled 44.7.

2.3 Equipment Repairs, Acquisitions, and Replacements

Table 2 lists the major equipment, materials, and supply items for which expenditures were proposed in the cooperative agreement budget during the first year. Most of the proposed items were acted upon.

As part of the facility program, NSF convened a review panel in Rapid City for two days in mid-September to consider a proposed upgrade package for the aircraft system (see Sec. 2.4). A completely new on-board data system, a new suite of Particle Measuring Systems, Inc., (PMS) probes, new ground data processing equipment, an updated telemetry system, and several other enhancements to the current facility capabilities were proposed to the review panel. Lack of a specific response to this proposal has led to some uncertainty as to how to proceed with the data acquisition system tape drive item listed in Table 2. It is unclear whether or not a new data system, with perhaps different mass storage requirements than the current system, might be acquired in the near future. Therefore, action on this item has been held up. The same is true of the planned rear-cockpit LCD display unit.

A new backup pressure transducer has not been purchased because one is available, surplus, from the NCAR Research Aviation Facility. The necessary paperwork has been filed with NCAR, but we have yet to receive the transducer. This transducer is of the same type as the one currently in use on the T-28 and is superior to NCAR's currently used transducers as far as sensitivity to temperature variations is concerned. Temperature sensitivity is an important consideration for the T-28, which normally flies without use of its on-board gas heater.

No new parachute has been purchased because we have an existing stock of chutes, one of which can be brought to current standards at no charge to us by the Air Force. This will be done locally at Ellsworth Air Force Base.

New brake discs for the T-28 are no longer available. Jon Leigh is currently looking for some salvage units.

TABLE 2

Status of Permanent Equipment, Materials and Supplies (Expendable) and Other Refurbishment Items as Listed in Cooperative Agreement

Item	Status
400 Hz/750 VA Inverter	Installed
Hydraulic Pump	Acquired
Data Acquisition System Tape Drive	Action delayed pending review of upgrade proposal
Back-up Pressure Transducer	Negotiating for NCAR RAF surplus unit
Miscellaneous Equipment	
Clock	Installed
A/D converter	Acquired
LCD rear-cockpit display	Action delayed pending review of upgrade proposal
Battery	Acquired
New Hoses	Received
New Parachute	Upgrading existing chute
Manifold Pressure Transducer	Acquired
Hail Spectrometer Anti-Streaking	Done
Spare Brake Discs and Blocks	Blocks acquired; new discs not available (searching for salvage discs)
Paint Aircraft	Done
Propeller Inspection	Done

Table 3 provides a summary of additional equipment repairs or acquisitions not called out in the first year budget. Items in this category are nearly as numerous as those in the "planned" category, as might be expected for an agreement covering research operations involving a nearly 40-year-old aircraft carrying research instrumentation whose average age is more than 10 years.

An auxiliary fuel boost pump had to be repaired in April, and the VOR unit in May. The 9-track Pertec tape drive used to record data in the PMS data acquisition system had a weak tensioning arm that required replacement the week prior to the beginning of field work in North Dakota; this was done at PMS's shop in Boulder. During the first week of the field season, the laser in the PMS FSSP failed; PMS replaced the laser and recalibrated the probe within a few days, and no significant flight opportunities were missed. A relatively routine repair of one of the T-28 J-W sensing heads was needed.

After the North Dakota field season was over, Jon Leigh found a T-28 A-type propeller on the used parts market. This was acquired, using mostly local funds that had been built up in an engine overhaul account prior to the beginning of the cooperative agreement. This should give the aircraft about 15 more minutes of on-station time per research flight than the C-type propeller currently on the aircraft. New de-icing boots have been put on this propeller, but it has not yet been installed on the aircraft. The hangar ceiling is too low for this installation, and we are awaiting warmer weather to do the job outdoors.

TABLE 3

"Unplanned" Major Equipment Acquisitions/Repairs

-- Fuel Boost Pump Repair
-- VOR Repair
-- Repairs to PERTEC Tape Drive
-- Repair to FSSP
-- Repair to J-W Sensing Head
-- New Propeller and De-ice Boots
-- Creating New Instrumentation Pylons
-- Rewiring Wings
-- New Compass

Wrinkles were found in the aircraft skin around the instrument pylon under the right wing when the PMS probes were removed in July to return them to NCAR's MMM Division (from whom we borrow them every summer for field work). A weight-reduction program that involved removing the present instrumentation wiring from the wings and replacing it with lighter-gauge wire had already been planned for the T-28 off-season. Since new wiring was to be installed, anyway, and the proposed instrumentation upgrade, if it were funded, would add one or more new probes to the instrumentation package, work has started to design and fabricate two new instrumentation pylons. These will replace the old single pylon, with one to be mounted on each wing. Calculations approximating airflow around the wing were performed to aid in the design. The new pylons will be somewhat shorter than the old one, and will be mounted about 5 feet in from the wing tips. According to the approximate airflow calculations, this should result in little tendency for ice particles to be preferentially oriented along the longitudinal axis of the wing due to airflow distortions introduced by the wing itself. (Non-random particle orientation can cause problems in interpretation of particle image data.)

The weight savings resulting from the new wiring alone should be between 50 and 100 pounds. The old wiring is now all removed. The new wire is on order, with the first shipments just starting to arrive. The new wiring will be placed inside soon-to-be-installed conduit. The use of conduit will make it easier in the future to modify or increase the wiring capacity of each wing.

A new compass was installed following failure of the old one on the return trip from Texas in October.

A couple of items not included in Table 3 are "in-the-works". One is a "quick engine change" engine package for the T-28, currently in the possession of the University of Washington. They would like to trade this to our facility for an appropriate piece of hardware. This exchange is currently in preliminary stages of negotiation.

The PMS probes (a 2D-C and FSSP) normally borrowed from what is now the MMM division of NCAR for use on the T-28 are in the process of being transferred to the NCAR RAF. This should result in better routine maintenance of the probes at no cost to the T-28 facility, and will probably increase the overall utilization of the probes. RAF has refused to take responsibility for the associated data acquisition system. It is a one-of-a-kind unit built by PMS in 1974 and represents pretty ancient technology by current RAF standards. Until funding becomes available to replace this unit, the T-28 facility agreement will have to bear the expense of keeping it in operating condition. It is in desperate need of refurbishment before this summer's field work begins in July. The recording of image data and some of the analog data was interrupted by intermittent noise during operations in North Dakota last summer. We hope that a knowledgeable contractor can perform the required work. It is anticipated that the

cost of maintaining this system for two or three more seasons will equal the present cost of acquiring a new state-of-the-art data system.

We are also negotiating with the Desert Research Institute to acquire a couple of electric field mills for use on the T-28 during summer field programs. It is hoped that electric field measurements will become part of the standard T-28 data product.

In preparation for the upcoming field season, the IAS-developed hail spectrometer is also being refurbished. There is a problem with the rate at which it generates interrupts to the MicroNOVA-based data system when it is generating image data. If these come in at too high a rate, a complete crash of both the MicroNOVA and PMS data systems results, for as yet unknown reasons. This problem must be solved to make the hailstone imaging capability functional.

2.4 Data System and Software Enhancements

With the current uncertainty about funds for the proposed instrumentation upgrade, our options for a piece-meal upgrade starting with a new data system capable of handling all of our analog and digital (including image) data are under review. This could result in enormous weight and space savings, as the old PMS data acquisition system we normally carry is very heavy and bulky compared to current systems with better capabilities. It might also result in a cost savings compared to maintaining our two current systems. Further discussion of this matter is contained in a trip report from a visit by T-28 facility personnel to the NCAR RAF in January. (See Appendix A.)

A considerable library of software for reduction of T-28 data existed in the Institute of Atmospheric Sciences prior to the beginning of the cooperative agreement. However, there was no local software for reduction of the image data from the PMS 2D-C probe. In the past, this reduction had always been performed by NCAR researchers. Since the beginning of the cooperative agreement, a considerable effort has been devoted to getting some 2D image processing capability developed locally. One of the most important aspects of this data processing is accurate determination of particle maximum dimension from the image data. A second important requirement is some form of particle type identification so that a size-to-mass relation appropriate for a given particle type can be applied for calculating water mass loading and precipitation rates from 2D image data.

Three pre-existing packages have been adapted to our local VAX or CYBER computer systems. The first is a version of the package developed by Andy Heymsfield and Joanne Parrish at NCAR (Heymsfield and Parrish, 1979). This package has been used for most of the PMS data reduction from T-28 flights in the past. This package is very

user-friendly and includes the capability to display single images or groups of images on a graphics terminal for relatively quick manual identification of particle types. It runs on our VAX. It also represents good continuity with techniques used to process the T-28 data that have been used in past published work. Modifications to its automated particle typing algorithms are under study, but we have yet to come up with an algorithm that seems universally appplicable to data from a variety of different cloud situations.

An automated particle-typing program from the Air Force Geophysics Laboratory (Hunter et al., 1984) has been successfully installed on our campus CYBER mainframe computer. We have been discussing with its developer, Herbert Hunter, the possibility of enhancing the program's capabilities for more clearly discriminating drops from roundish graupel images. This program is considerably more complex than the Heymsfield-Parrish program and is correspondingly more expensive to run. We have yet to decide whether the additional expense provides correspondingly more accurate and/or useful results.

Finally, particle-typing algorithms developed by Ed Holroyd (Holroyd, 1987), of the Bureau of Reclamation, have been grafted onto the Heymsfield-Parrish program package. Holroyd's algorithms appear to be more capable of automatically discriminating between the various particle types typically encountered in T-28 cloud penetrations than the cruder (but faster) Heymsfield-Parrish technique. This technique question is currently under further investigation.

Software has been developed for plotting aircraft tracks from either aircraft-recorded VOR/DME data or FAA tracking radar data. Various custom software packages for specific types of data processing requested by researchers connected with the 1987 North Dakota field program have also been developed.

2.5 Proposal for Facility Upgrade

During the spring and summer of 1987, a plan for upgrading the T-28 facility to improve its capability to support user research projects was developed. This plan was presented to NSF in our Research Proposal 88-9, submitted in August 1987. It outlined the upgrade needs in the major areas of meteorological instrumentation, data acquisition system development, air-to-ground data telemetry, and ground data reduction. Some additional related upgrades were also suggested.

The proposal was reviewed by an NSF advisory panel that met in Rapid City on 16-17 September. We are still awaiting the panel and NSF response to our proposal. Decisions as to how to proceed with facility upgrade activities must await that response.

2.6 Travel by Facility Personnel

Norm Vine took the aircraft to Minnesota in April 1987 for a propeller inspection; to Salt Lake City for VOR repair and work on the SF_6 analyzer installation in May; and to Texas for its paint job in September.

Jon Leigh flew to Salt Lake City after Norm Vine took the T-28 there in May, for fitting of the tracer gas detector for the North Dakota field project.

All facility personnel participated in last summer's field project. In addition, Gary Johnson, Andy Detwiler, Ken Hartman, and Bob Thompson made a group visit to the NCAR RAF in January 1988, to discuss various aspects of aircraft facility operations. A trip report from that effort is contained in Appendix A.

Paul Smith attended the RAF Advisory Panel meeting in Boulder in October, and is also scheduled to attend the spring meeting in April. Individual trips made on behalf of the facility by Andy Detwiler included trips to the University of Wyoming in April, a Hailswath planning meeting last May in Bismarck, and the on-going field program at New Mexico Institute of Mining and Technology in July. He will attend the upcoming American Meteorological Society Severe Storms Conference in Baltimore to present a geographical comparison of past T-28 observations.

2.7 Promotional Activities

Literature has been prepared for distribution to researchers interested in using the T-28 in their research programs. It includes a short photocopied brochure describing the evolution of the T-28's research capabilities and detailing its current capabilities. This brochure was written so as to be easily modifiable as the aircraft's instrumentation and capabilities are improved with time. Along with the brochure goes a form detailing the information that must be supplied to the facility manager when a request is made for T-28 use in a research program.

Availability of the T-28 for support of 1988 summer research projects was announced via the AMS Newsletter in advance of the fall 1987 RAF Advisory Panel meeting. A joint notice was recently put together with the University of Wyoming concerning the availability of their King Air and our T-28 as national research aircraft facilities. The text of the notice is included with this report as Appendix B. The notice has been sent to all UCAR member representatives individually and also submitted to the Bulletin of the American Meteorological Society and the Airborne Science Newsletter for publication in the next issues to go to press.

Norm Vine and Andy Detwiler made a presentation on airborne severe storm research to the local unit of the Civil Air Patrol in January. Norm did his best to discourage the pilots present from flying into thunderstorms. Andy is scheduled to make several more presentations to South Dakota public school groups on airborne research later this spring, as well as to present a seminar on T-28 research results at SUNY Albany following his trip to Baltimore later this month.

Video tape footage of T-28 research activities is being assembled. We hope to collect enough this summer during the research project in Illinois to combine with the North Dakota footage acquired last year into a short, interesting video suitable for showing to audiences at the level of the informed layman.

3. FUTURE PLANS

3.1 Research Projects to be Supported

Proposed T-28 participation in two 1988 field projects was considered by the Facility Manager and the NCAR RAF Advisory Panel in October. The Illinois PACE project (with potential ties to the 3CPO program to be held in the same region in May and June), which had been delayed from 1987, put in a request for the T-28 for 1988, as did the Hailswath II field project. The Hailswath project was delayed due to lack of funding from the NSF (which would have been the primary sponsor of most of the research proposed for that project). A definite commitment was made to support the Illinois program for the summer of 1988.

Current plans call for the T-28 to be based in Champaign-Urbana, Illinois, from 11 July through 5 August in support of the PACE program under the direction of Stanley Changnon and the Illinois State Water Survey. It does not appear that there will be much overlap with the 3CPO program. The T-28 will be investigating precipitation development and seeding effects in Illinois convective clouds ranging up to the size of large thunderstorms. It will coordinate with a seeder aircraft, one other cloud physics aircraft, and possibly a NOAA P-3. Detailed flight procedures will be worked out later this spring.

A request has been received from the Steering Committee for Hailswath II for advance reservation of the facility, for use in the summer of 1989. This request will be reviewed at the RAF Advisory Panel meeting in April. No other requests are pending at this time, although inquiries have been received about possible use of the T-28 in FAME (Florida) in 1990.

3.2 Facility Development Activities

Work to maintain the aircraft and associated data system will continue as required. The wing rewiring task will be completed prior to the 1988 summer project in Illinois. Major planned items listed in the proposed budget for the second year of the cooperative agreement include scheduled corrosion inspection of the new propeller and overhaul of a spare carburetor to provide a serviceable replacement unit. As noted in Sec. 2.2, maintenance of the PMS DAS will now become our responsibility. A request is also pending to acquire a VAX tape drive to improve our data support capabilities.

One change in plans has been facilitated by a reduction in the indirect cost rate (from 44.8% to 40.0%). The additional funds thus made available have been allocated in the proposed budget to purchase a complete new air-to-ground telemetry system, instead of just the receiver as originally proposed. Advantages of this kind of system were reviewed during the recent facility staff visit to the NCAR RAF

(see Appendix A). Of particular importance to the T-28 operations will be the capability to monitor the data system status on the ground and, if necessary, send up re-booting commands to restart the system.

We are still awaiting a response to our facility upgrade proposal of August 1987, and hope to be able to begin work on at least part of the upgrade in the near future. The most pressing need is in the on-board data acquisition system, because there is considerable doubt about how much longer the PMS DAS can be operated. An examination of what might be accomplished in piece-meal fashion with limited funds is already underway.

4. KEY PERSONNEL

There have been no changes in key personnel since the inception of the cooperative agreement.

5. PUBLICATIONS

Detwiler, A. G., 1987: Armored T-28 research aircraft facility. Bulletin 87-5, Institute of Atmospheric Sciences, S.D. School of Mines and Technology, Rapid City, SD. 21 pp.

Detwiler, A. G., 1987: Geographic variation of severe storm microphysics and dynamics. Presented at 15th Conference on Severe Local Storms, 22-26 February 1988, Baltimore, MD.

6. REFERENCES

Heymsfield, A. J., and J. L. Parrish, 1979: Techniques employed in the processing of particle size spectra and state parameter data obtained with the T-28 aircraft platform. NCAR Technical Note NCAR/TN-137&IA, National Center for Atmospheric Research, Boulder, CO. 78 pp.

Holroyd, E. W., III, 1987: Some techniques and uses of 2D-C habit classification software for snow particles. J. Atmos. Ocean. Tech., 4, 498-511.

Hunter, H. E., R. M. Dyer and M. Glass, 1984: A two-dimensional machine classifier derived from observed data. J. Atmos. Ocean. Tech., 1, 28-36.

Knight, N. C., A. J. Weinheimer and M. B. Steiner, 1986: The use of powdered iron as a tracer in hailstorm research. Preprints Joint Sessions of 23rd Conf. Radar Meteor. and Conf. Cloud Physics, Snowmass, CO, Amer. Meteor. Soc., JP1-JP2.

Stith, J. L., and R. L. Benner, 1987: Application of fast response continuous SF_6 analyzers to in situ cloud studies. J. Atmos. Ocean. Tech., 4, 599-619.

Stith, J. L., D. A. Griffith, R. L. Rose, J. A. Flueck, J. R. Miller, Jr., and P. L. Smith, 1986: Aircraft observations of transport and diffusion in clouds. J. Climate Appl. Meteor., 25, 1959-1970.

Stith, J. L. M. K. Politovich, R. F. Reinking, A. Detwiler and P. L. Smith, 1988: Investigating mixing and the activation of ice with gaseous tracer techniques. Preprints 10th Intn'l. Cloud Physics Conf., IAMAP/IUGG, 15-20 August 1988, Bad Homburg, FRG.

7. BUDGET INFORMATION

7.1 General

This is a request for second year funding under a four year cooperative agreement. This second year funding is for $190,000, less the $16,900 user fee (cost recovery funds) collected last year, from the North Dakota Atmospheric Resources Board summer of 1987 project, making the NSF request for new monies equal to $173,100.

7.2 Salaries and Benefits

Salary rates are those set by the Regents of Education of the State of South Dakota for FY1988 and inflated by 5% for FY1989. (Actual approved FY1989 rates will be charged the sponsor.)

7.3 Permanent Equipment

An air-to-ground telemetry system is being requested (Section 3.2) in this second year of the agreement at an estimated cost of $7,500.

7.4 Indirect Costs

The latest approved indirect cost rate approved by the cognizant government audit agency of the South Dakota School of Mines and Technology is 40.0% of salaries and wages, exclusive of overtime. All salaries and wages in this renewal qualify for the on-campus rate.

The cognizant Government Audit Agency for this institution is:

Director, Division of Cost Allocation
Regional Administrative Support Center
Department of Health and Human Services
Room 1185, Federal Office Building
1961 Stout Street
Denver, CO 80294

7.5 Cost Sharing

This budget will not be charged for the effort expended by the T-28 scientist, Dr. A. G. Detwiler. The State of South Dakota has appropriated some funds to support this position as cost-sharing. Dr. Detwiler will be cost shared at 10 months and Dr. Smith at 0.5 months for this second year funding; thus, the cost sharing including benefits and overhead is $67,367.

(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. PI: P. L. Smith	1.50			$ 9,839	$
2.					
3.					
4.					
5. (1) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)	0			-0-	
6. (2) TOTAL SENIOR PERSONNEL (1-5)	1.50			9,839	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. ( ) POST DOCTORAL ASSOCIATES					
2. (4) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	26.32			79,902	
3. ( ) GRADUATE STUDENTS					
4. ( ) UNDERGRADUATE STUDENTS					
5. (1) SECRETARIAL-CLERICAL				3,282	
6. ( ) OTHER					
TOTAL SALARIES AND WAGES (A+B)				93,023	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				14,884	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A+B+C)				$107,907	
D. PERMANENT EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $1,000:)					
1. Telemetry system $7,500					
TOTAL PERMANENT EQUIPMENT				7,500	
E. TRAVEL 1. DOMESTIC (INCL. CANADA AND U.S. POSSESSIONS)				7,629	
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				9,094	
2. PUBLICATION COSTS/PAGE CHARGES				1,960	
3. CONSULTANT SERVICES				-0-	
4. COMPUTER (ADPE) SERVICES				423	
5. SUBCONTRACTS				-0-	
6. OTHER				18,278	
TOTAL OTHER DIRECT COSTS				29,755	
H. TOTAL DIRECT COSTS (A THROUGH G)				$152,791	
I. INDIRECT COSTS (SPECIFY) On-campus rate @ 40.0% of Total Salaries and Wages					
TOTAL INDIRECT COSTS				37,209	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				$190,000	
K. ~~RESIDUAL FUNDS~~ (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPM 252 AND 253) Cost Recovery Fund				16,900	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ 173,100	$

PI/PD TYPED NAME & SIGNATURE*: Paul L. Smith — Paul L. Smith — DATE: 15 Feb 1988

INST. REP. TYPED NAME & SIGNATURE*: Timothy G. Henderson — Sharon L Reid for — DATE: 26 Feb 1988

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INDIRECT COST RATE VERIFICATION
Date Checked | Date of Rate Sheet | Initials - DGC | Program

NSF Form 1030 (1-87) Supersedes All Previous Editions

BUDGET EXPLANATION PAGE

Second Year: 15 May 1988-14 May 1989

	COLLEGE FY	EFFORT MAN-MO	MONTHLY SALARY	REQUESTED FUNDS	MAN-MO	COST SHARING FUNDS
A. SENIOR PERSONNEL:						
1. Principal Investigator						
P. L. Smith	1988	0.25	6,297	$ 1,574	0.00	$ -0-
	1989	1.25	6,612	$ 8,265	0.50	$ 3,306
2. Research Scientist						
A. G. Detwiler	1988	0.00	3,826	$ -0-	1.50	$ 5,739
(State supported)	1989	0.00	4,017	$ -0-	8.50	$ 34,145
Subtotal				$ 9,839		$ 43,190
B. OTHER PERSONNEL:						
2. Other Professionals						
a. Research Engineer						
G. N. Johnson	1988	0.75	4,152	$ 3,114		
	1989	5.25	4,360	$ 22,890		
b. Programmer						
K. R. Hartman	1988	0.75	2,276	$ 1,707		
	1989	5.25	2,390	$ 12,548		
c. Research Pilot						
N. R. Vine	1988	0.40	4,080	$ 1,632		
	1989	2.60	4,284	$ 11,138		
d. Aircraft Mechanic						
J. E. Leigh	1988	1.50	2,275	$ 3,413		
	1989	9.82	2,389	$ 23,460		
5. Secretarial	1988	0.30	1,574	$ 472		
	1989	1.70	1,653	$ 2,810		
Subtotal				$ 83,184		
TOTAL SALARIES AND WAGES:				$ 93,023		$ 43,190
C. FRINGE BENEFITS:						
1. Staff @ 16.0% of Salaries and Wages				$ 14,884		$ 6,910
TOTAL SALARIES, WAGES, AND FRINGE BENEFITS:				$ 107,907		$ 50,100

*Salaries include a vacation accrual ajustment.

BUDGET EXPLANATION PAGE

Second Year: 15 May 1988-14 May 1989
(continued)

	REQUESTED FUNDS
D. PERMANENT EQUIPMENT:	
1. Telemetry System	7,500
Subtotal	$ 7,500
E. TRAVEL:	
1. Domestic	
a. Travel to project planning meetings and scientific conferences	5,620
b. Local mileage for required travel between campus and airport (T-28 location)	2,009
Subtotal	$ 7,629
G. OTHER DIRECT COSTS:	
1. Materials and Supplies	
a. Jacks	930
b. Pressure washer	350
c. Parts cleaner	200
e. Miscellaneous small parts and repairs to support operation of T-28 and instrumentation	3,600
f. Fuel/oil for T-28 test flights (24 hrs @ $116/hr)	2,784
g. Fuel oil for heating hanger (600 gal @ $1.05/gal)	630
h. Miscellaneous supplies	600
Subtotal	$ 9,094
2. Publication Costs	
a. Paper for scientific conference	300
b. Journal paper	1,410
a. Miscellaneous reproduction	250
Subtotal	$ 1,960
4. Computer (ADPE) Services	
a. VAX; est. 100 hrs @ $4.23/hr	423
Subtotal	$ 423

BUDGET EXPLANATION PAGE

Second Year: 15 May 1988-14 May 1989
(continued)

	REQUESTED FUNDS	COST SHARING FUNDS
G. OTHER DIRECT COSTS: (continued)		
6. Others		
a. Propeller inspection	1,000	
b. Carburetor overhaul	1,500	
c. Rental of hangar/shop facility (includes electricity), 12 mo @ $420/mo	5,040	
d. Telephone service for hangar/shop, 12 mo @ $44/mo	528	
e. Trash collection service, 12 mo @ $22/mo	264	
f. Liability coverage on T-28 and accident insurance for pilot	5,541	
g. Annual subscription to federal airworthiness directives	597	
h. Maintenance and repair services that are beyond in-house capability	3,000	
i. Long distance telephone calls	500	
j. Miscellaneous services	308	
Subtotal	$ 18,278	
H. TOTAL DIRECT COSTS:	$ 152,791	$ 50,100
I. INDIRECT COSTS: On campus rate @ 40.0% of Total Salaries and Wages	$ 37,209	$ 17,276
J. TOTAL COSTS:	$ 190,000	$ 67,376
K. LESS T-28 USE CHARGES (COST RECOVERY FUNDS):	$ 16,900	
L. AMOUNT OF THIS REQUEST:	**$ 173,100**	

8. CURRENT AND PENDING SUPPORT

8.1 Principal Investigator, Paul L. Smith

A. Current Support:

1) Supporting Agency: North Dakota Weather Modification Board
Project Title: Continuing Investigations Related to the Development of Evaluation Techniques for the North Dakota Cloud Modification Project
Award: $189,800
Period of Award: 1 July 1987-30 June 1988
Commitment: 3.0 months
Location: Analysis is at Rapid City, SD

2) Supporting Agency: National Science Foundation
Project Title: RUI: Completion of Studies of Precipitation Processes in CCOPE Hailstorms
Award: $45,000
Period of Award: 1 March 1987-28 February 1988
Commitment: 0.5 months
Location: Rapid City, SD

3) Supporting Agency: National Aeronautics and Space Administration
Project Title: Microphysical and Electrical Structure of Small Convective Systems in the Southeastern Part of the United States
Award: $60,000
Period of Award: 20 May 1987-19 May 1988
Commitment: 1.2 months
Location: Rapid City, SD

4) Supporting Agency: National Science Foundation
Project Title: Armored T-28 Aircraft Facility for Research Requiring Storm Penetrations
Award: $200,000
Period of Award: 15 May 1987-14 May 1988
Commitment: 2.4 months
Location: Rapid City, SD

B. Pending Support:

1) Supporting Agency: North Dakota Atmospheric Resources Board
Project Title: Continued Research Investigations Related to the North Dakota Cloud Modification Project
Amount Requested: $149,800
Period of Request: 1 July 1988-30 June 1989
Commitment: 2.5 months
Location: Rapid City, SD

B. Pending Support: (Paul L. Smith, continued)

2)	Supporting Agency:	National Aeronautics and Space Administration
	Project Title:	Microphysical and Electrical Structure of Small Convective Systems in the Southeastern Part of the United States
	Amount Requested:	$60,959
	Period of Request:	20 May 1988-19 May 1989
	Commitment:	1.1 months
	Location:	Rapid City, SD
3)	Supporting Agency:	National Science Foundation
	Project Title:	Armored T-28 Aircraft Facility for Research Requiring Storm Penetrations
	Amount Requested:	$173,100
	Period of Request:	15 May 1988-14 May 1989
	Commitment:	2.4 months
	Location:	Rapid City, SD
4)	Supporting Agency:	National Aeronautics and Space Administration
	Project Title:	Improved Snow Cover Mapping and Snowmelt Runoff Estimates Derived from SAR Imagery
	Amount Requested:	$60,000 (first year)
	Period of Request:	1 October 1988-30 September 1989
	Commitment:	0.5 months
	Location:	Rapid City, SD
5)	Supporting Agency:	U.S. Army White Sands Missile Range
	Project Title:	Meteorological Effects Research and Development Through the Use of Remotely Sensed Data and Space Technology
	Amount Requested:	$260,641 (first year)
	Period of Request:	1 February 1988-31 January 1989
	Commitment:	1.8 months
	Location:	Rapid City, SD
6)	Supporting Agency:	DRI, Univ. of Nevada-Reno
	Project Title:	Research Aircraft Support for Federal/State Cooperative Program Investigations in Illinois
	Amount Requested:	$40,127
	Period of Request:	1 July 1988-31 Dec 1988
	Commitment:	0.4 months
	Location:	Rapid City, SD

B. Pending Support: (Paul L. Smith, continued)

7)	Supporting Agency:	National Science Foundation
	Project Title:	Aircraft and Radar Investigations of Hailstorm Processes as Part of Hailswath II
	Amount Requested:	$182,500
	Period of Request:	1 January 1988-31 December 1988
	Commitment:	3.5 months
	Location:	Rapid City, SD
8)	Supporting Agency:	National Science Foundation
	Project Title:	RUI: Completion of Studies of Precipitation Processes in CCOPE Hailstorms
	Amount Requested:	$38,700
	Period of Request:	1 May 1988-30 April 1989
	Commitment:	0.4 months
	Location:	Rapid City, SD

APPENDIX A

M E M O R A N D U M

28 January 1988

TO: Paul L. Smith
T-28 Facility Manager

FROM: Robert C. Thompson
Gary N. Johnson
Kenneth R. Hartman
Andrew G. Detwiler

SUBJECT: Visit to NCAR RAF on 25 January 1988

Gary

One purpose of the trip was to discuss what is currently being done by RAF in the data acquisition field, and to see if we might be able to benefit from their experience. Also, we wished to talk about the status of the PMS probes and DAS used on the T-28 and what might be done to refurbish them.

The airborne data system designed at RAF is based upon multiple Motorola 68000-series microprocessors which are joined on a common VME bus. This design could be used quite easily on the T-28, since much of the instrumentation is the same. The primary advantage to our implementation of this design is the fact that most of the development work is already done. The primary disadvantage may be the cost. Although we don't have any real data with which to compare an AT-based system with a 68000-based system, it seems quite likely that the latter will end up costing more. On the other hand, we may be better able to save money by in-house fabrication of NCAR's design. We will be studying this tradeoff in the coming weeks.

Bob

From the initial tour of the RAF facility, I could tell that we had come to the "Right Place" to discuss airborne data acquisition techniques. The general architecture of the DAS systems in use at NCAR appears to me to be quite sound. However, they employ a significant computing ability for real-time onboard displays. In the case of the T-28, major portions of the real-time displays would need to be modified to provide the pilot and the personnel on the ground with the proper information.

From the discussions with Kim Weaver and Al Cooper, I feel that, given the time and money, we could construct our own replacement DAS for the T-28. I believe that constructing our own DAS has two

advantages over a turn-key system. First, a significant financial savings may be realized. This additional money could be used for other equipment, salaries, etc. Second, if the personnel that use and maintain the DAS are also the same personnel that have constructed the DAS, a much stronger understanding of the system's abilities and limitations will be achieved. Also modifications should be easier made to the DAS.

It would appear that NCAR/RAF could make most all of their designs available for our use. Since their systems are "tried and true," we could learn from their mistakes and benefit from their experience.

Gary

We also discussed the status of the PMS probes we currently borrow from NCAR MMM, and how to get them refurbished. Darrel Baumgardner is part-owner of a company which could do the necessary repair and calibration work, but the company could not work on the probes as long as they are NCAR property. It was suggested that the ownership of the DAS and probes could be transferred to RAF, and then the RAF technicians could do the work at no cost. If the probes and DAS are transferred to RAF, we would want to have some formal usage arrangement so that there would be no conflict during and before field projects.

Since we are also planning to upgrade our telemetry capability on the T-28, I was most interested in learning more about the new system developed by Kim Weaver and Craig Walther. The system they developed was used in Germany last fall, and worked quite well to about 75 miles range. The radio equipment and modems were purchased off-the-shelf and could be quite easily duplicated on the T-28. The system has bi-directional communications capability and is controlled by a separate microprocessor on the VME bus, which is more elaborate than originally envisioned for our use. The basic hardware may be feasible for our use, however, which will also be a subject for further study.

The subject of navigation and tracking was also brought up during our afternoon discussions. NCAR uses inertial navigation and LORAN-C as sources of track information, but they have also started using a GPS satellite receiver on the King Air. Apparently there are enough satellites flying now for several hours coverage per day. In tests conducted last fall they were able to get 25-meter positional accuracy using one small GPS receiver. The cost of the system was around $15,000. It seems that using GPS may not be out of the question for the T-28 after all.

Ken

A suggestion to provide T-28 data to users in a format "identical" to that used by RAF seems to be a good one. Their format includes an initial header file which contains descriptions and pointers to the actual data locations on subsequent file(s). This provides flexibility among data sets. Whereas the T-28 may have quite a different, perhaps more limited, subset of instrumentation, if we followed their formatting scheme other users would have little difficulty in reading our data. For our own in-house processing we could perhaps maintain a dual file system until programs which access the data are converted to reading the new format. Whether or not we would wish to keep our present reduced data format depends on how easy it would be to maintain with all the proposed system changes.

From my perspective there seems to be pluses and minuses to having either a single computer running the show on board the T-28 or multiprocessors coordinated to divide up some of the tasks. Personally I have no experience with the latter approach, but perhaps much of the software can be borrowed from NCAR if we chose to go that way. Implementing any new system for this coming summer becomes scarier as time becomes shorter, of course. The decision of whether or not to go the multiprocessor route hinges upon our anticipated "work load" for the computer, whether a single processor will keep up with the data acquisition, telemetry, real-time processing that might be proposed, etc. -- plus any financial considerations.

Andy

General data processing was discussed with Dick Friesen. NCAR's aircraft data systems are much more sophisticated than ours, but their basic processed products are about the same as ours. They are set up to automatically process much larger volumes of data. Their GENPRO software package has capabilities to do more sophisticated processing than we currently can -- if a user knows the package well enough. Digital filtering is one area in which we don't do much but in which NCAR people have done quite a bit.

RAF has relatively sophisticated networked aircraft data systems but has found nothing more reliable than nine-track tape as a recording media. Sailplane experience with streaming tape cartridges last summer was not positive. Hard disc units have worked well in the King Air and Electra but are used only for booting up operating systems, not for data storage.

Al Cooper discussed 2D image processing. He recommends we add a circle-fit routine to our "habit" identification algorithm (there is one in Ed Holroyd's package, I think, that we will have when we get it running, here). Al says it is a good way to discriminate graupel from drops. He also pointed out characteristic images of drops streaming from 2D-C probe tips in our 1987 data and discussed drop oscillations as a possible cause of some oddy "squished" drop images in our COHMEX data.

Al did not put much stock in sophisticated algorithms for classifying 2D images. He and Andy have some differing ideas on this point. It is agreed, though, that the present state-of-the-art in sophisticated classification schemes is such that the sophisticated routines are not much more successful at discriminating particle type than the simplest schemes.

All NCAR aircraft will be carrying O_3 and CO instruments within the next year or two. Al says that the kind of air source tracing that can be done with CO and O_3 measurements is becoming common practice in much field work.

One option for our facility to explore in this climate of tight money is to share acquisition costs of new equipment with RAF as well as share the equipment once it is acquired. This could work if there were a well-thought-out agreement on usage priorities spelled out ahead of time. We normally fly for only a short period each year, whereas RAF is typically in the field year-round with one or more aircraft. Norm Zrubic offered his aero engineering services if we require them. He has done some nice work on the NCAR aircraft.

The overall impression I got from talking to Cooper, Warren Johnson and Paul Spyers-Duran is that they expect Hailswath will go in '89. Al Cooper made the somewhat curious comment that the Hawaiian project will eventually take place, too, and that it will be planned so as to insulate it from the kind of excessive dependence on NSF budget maneuvering that is taking place this year.

Bob

Another item that is worth mentioning is the general attitude of the personnel at NCAR/RAF. I was pleased that they were so willing to take the time to discuss possible cooperative efforts. I believe that both parties would have much to gain by a strong cooperative effort.

Ken

I was very impressed with both the cordiality and the competence of the people we met. They seemed very willing (eager?) to lend assistance in both hardware and software areas.

RCT/GNJ/KRH/AGD:slp
cc: R. J. Gowen

APPENDIX B

The University of Wyoming King Air (B-200T) research aircraft and the South Dakota School of Mines and Technology's armored T-28 aircraft are available as national facilities under cooperative agreements with NSF for use in support of research in the atmospheric sciences. The Wyoming King Air is equipped comparably to the NCAR King Air. The new onboard data system and accompanying computer trailer allows extensive realtime data display and in-depth field analysis. Scientists wishing to include the aircraft in their research programs should contact the Department Head, Atmospheric Science Department, P.O. Box 3038, University Station, Laramie, Wyoming 82071, (307/766-4947). The mechanism for obtaining use of the Wyoming King Air is similar to that of the NCAR King Air. NSF funded scientists will be allocated the aircraft for a fixed period of time and operational expenses for a fixed number of flight hours. Non-NSF scientists are expected to reimburse for all costs.

The T-28 is equipped to make atmospheric state, vertical wind and cloud microphysical measurements; limited provisions can be made for mounting user-supplied instrumentation. The aircraft is armored to permit safe penetrations of hail-bearing thunderstorms. Data reduction and preliminary analysis in the field and afterward are provided by the facility. Scientists wishing to include the aircraft in their research programs should contact the T-28 Facility Manager, Institute of Atmospheric Sciences, South Dakota School of Mines and Technology, 501 East St. Joseph Street, Rapid City, South Dakota 57701-3995, (605-394-2291) for information about costs, scheduling, or technical matters, and for submitting requests for T-28 research flight support. All users are charged for incremental costs

associated with the T-28 field operations; non-NSF-funded users are assessed an additional daily use charge.

Both aircraft are allocated through the same procedures and on the same cycle as the National Center for Atmospheric Research (NCAR) Research Aviation Facility (RAF) fleet. The RAF Advisory Panel meetings in April and October, at which requests for flight support are reviewed, are announced through the Bulletin of the American Meteorological Society and other channels. Flight support requests must be submitted to NCAR, the University of Wyoming, or South Dakota School of Mines and Technology at least two months before the Advisory Panel meetings. NSF research proposals involving the aircraft must be submitted to NSF at least four months before the Advisory Panel meeting.