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(NATIONAL HAIL RESEARCH EXPERIMENT - ARMORED AIRCRAFT WORK PLANS - 1972)

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1. INTRODUCTION AND BACKGROUND

The South Dakota School of Mines and Technology (SDSM&T) armored T-28 will participate in the 1972 National Hail Research Experiment (NHRE) under a continuation of Subcontract No. NCAR 182-71. The project is sponsored by the National Science Foundation (NSF) under the direction of the National Center for Atmospheric Research (NCAR).

The research of the T-28 will be carried out in conjunction with other university groups and government agencies as outlined in the NHRE Operations Plan 1972. These work plans are intended to be a supplement to that document.

2. OBJECTIVES

The overall objective of the T-28 research is to use the armored aircraft to obtain data within and in the immediate vicinity of hailstorms. The specific objectives include:

1) Obtaining measurements of updrafts in the regions of hail formation;

2) Determining the composition of high radar reflectivity zones;

3) Obtaining a "first-look" at ice-water budgets in hailstorms; and

4) Using the data gathered by the T-28 as input to numerical models of hailstone and hailstorm growth being developed under other sponsorship.

The type of investigations planned include determination of the relationship between vertical velocity and temperature profiles, liquid water content and nature of the precipitation produced by the storm.

3. PERSONNEL

The field operation phase of the project will be carried out by the following individuals:

NAME	TITLE
Dennis J. Musil	Project Meteorologist
Wayne R. Sand	Pilot
Kenneth E. Jasper	Technician
Leonard N. Block	Mechanic

The project meteorologist will be located at the field project site at Grover, while the other individuals will be located in Cheyenne with the T-28.

Overall direction for the project is provided by Dr. Richard A. Schleusener, who is also principal investigator for the studies being carried out by the T-28. In addition, several other staff members of the Institute of Atmospheric Sciences (IAS) will be involved with the various phases of the project as outlined in Research Proposal 71-8. These include such items as installation and calibration of the meteorological data gathered by the T-28, and assisting in the interpretation of the gathered data.

4. CLOUD PENETRATION PROCEDURES

The primary mission of cloud penetration will be carried out under the direction of the project meteorologist within the general framework of the overall NHRE project. Decisions on flights to be undertaken will be the responsibility of the project meteorologist after coordination with the NHRE operations director. Telephone communications will be maintained between Grover and Cheyenne to provide notification of an impending launch of the T-28. Several phone calls may be necessary on a potential "go" day, in order to keep the T-28 crew abreast of activities at Grover.

A telephone call to Cheyenne will be made by the project meteorologist to initiate a research flight by the T-28. The pilot will be given general information to direct him to the vicinity of the storm on which penetrations are to be made. This will be done during the telephone call or via radio after the aircraft is airborne. After takeoff the aircraft should fly from Cheyenne to Grover arriving at the entry point at an altitude of 15K feet. At this point the T-28 can either hold or climb to altitude depending on the meteorological situation and clearance from FAA. Once on station, the project meteorologist will identify an IP and a heading to intercept the cloud at the proper place. This information will be given to an FAA coordinator located at Grover, who in turn will relay the information to aircraft control located at Longmont. Vectoring will be provided by the FAA at Longmont and any changes in heading will be cleared through the FAA coordinator at Grover. Although direct communications will be maintained between the pilot and the project meteorologist via radio frequency 123.05, no course changes are planned by this means without prior FAA approval.

The T-28 will be directed to make repeated passes beginning at 24K ft, progressing downward at 2K ft intervals to lower altitudes for each successive pass until the 0C isotherm or cloud base has been reached. A climb-out will then be made to 24K ft and further penetrations will be made provided enough fuel is available. It is recognized that it may be necessary to delay successive penetrations at any point to allow for the melting of structural ice, even though this did not constitute a major problem during past use of the T-28. The pilot will have the final decision on any matters dealing with flight safety.

Initially the T-28 will not be requested to penetrate storms exhibiting a maximum radar reflectivity greater than 55 dBz (10-cm). As experience is gained, this limitation can be removed when it becomes obvious that the aircraft can safely penetrate storms of higher reflectivities.

Continual coordination will be maintained between the project meteorologist and the FAA coordinator and his affiliates at Longmont to provide updated information concerning correct flight paths. Coordination also will be maintained between the project meteorologist

and the pilot concerning the selection of proper flight paths, in order to verify that pilot and radar observations are being made on the same volume of air.

Upon entry and exit for each penetration, the pilot will transmit information concerning the penetration directly to the project meteorologist at Grover via radio frequency 123.05. This will be done by use of a code developed by IAS personnel during 1970 and use of the event code channel on the DL-620A data recording system. The code scheme is given as follows:

LINEUP

S - Start recorder and switch to event code 8.
T - Time
A - Altitude
H - Heading

ENTRY

Switch to event code 7 at time of entry.

EXIT

Switch to event code 8 at the time of exit.
T - Time
A - Altitude
H - Heading
H - Hail encountered (yes or no)
I - Ice crystals (yes or no)
R - Rain (yes or no)
T - Turbulence remarks
R - General remarks
S - Stop recorder and switch to event code 9.

The above information, which will be recorded by the project meteorologist as well as on the voice recorder in the T-28, will provide valuable information necessary for an after-the-fact reconstruction of the mission. A copy of the recording form to be used at Grover is included as Appendix A. Pertinent information considered important by the pilot can be placed on the voice recorder at any time by operating it independently of the system described above.

The event code channel on the DL-620 system must be used to provide information required for computer reduction of the data. The meaning of the codes is given as follows:

DIGIT	EVENT
9	Out of cloud, recorder in 1-min mode. Use during climb and descent.
8	Use during lineup prior to cloud penetration and upon exit from a cloud. Recorder switches to continuous mode and Kyle device is turned on. A yellow button has been installed to switch to this code.
7	In cloud, continuous mode. A white button has been installed to switch to this code.

Other digits are available for other events; however, it is felt that time restrictions on the pilot will be such that only the simple scheme shown above can be maintained.

The comments in this section are made with the assumption that radar information at or near the level of penetration and a flight track of the T-28 will be available through the NHRE data display system. Furthermore, the information should be presented on the same display simultaneously. If such information is not available, the mission of the T-28 is severely limited from a safety and tracking standpoint. Detailed radar support requirements have been outlined previously and are included as Appendix B. It is recognized that not all these requirements can be available for the 1972 field season and therefore are listed in descending order of importance as pertains to the T-28 missions.

5. USE OF TIME-SHARE COMPUTING SYSTEM

It is planned to make use of the United States Bureau of Reclamation (USBR) time-share terminal at Grover to obtain cloud model information expected to be useful in forecasting size of cloud and hail in the project area. The procedure makes use of the results from two models developed by IAS personnel; one is a one-dimensional steady state cloud model (Hirsch model) and the other is a one-dimensional non-steady state hailstone growth model (Musil model).

A basic requirement is that the NHRE soundings for 0800 MDT be placed on the USBR system as soon as possible after the observation. Then the project meteorologist is able to request information from the system using an existing version of the Hirsch model, which produces various cloud parameters as a function of height for different updraft radii. It has been found that observed hailstone sizes correlate quite well with computed sizes from the Musil model, using values of maximum updraft (WMX) and the temperature at that level (TMX) from the Hirsch model. Hence, such values can be used in a nomogram summarizing results from the Musil model to obtain a reasonable forecast of expected maximum hailstone size for the given sounding conditions. The information will be made available to Grover personnel in the form of showing maximum forecast hail diameter versus cloud top. Additionally, this will provide a convenient means to verify the model results with actual hail occurrences. The results of the Hirsch model also provide for a verification of model with actual T-28 measurements of updraft inside the cloud, as well as other parameters such as temperature.

It is expected that approximately one-half hour of telephone time per day will be required for the above purpose on the time-share system.

6. BRIEFINGS

6.1 Daily Weather Briefings

IAS weather personnel will take part in the daily NHRE weather briefings at Grover to the fullest extent possible. It is recognized that personnel in Cheyenne may be prevented from regular attendance at the meeting due to travel distance and possible maintenance commitments for the T-28. The project meteorologist can present results of the cloud model computer runs described in the previous section at this time.

6.2 Rapid City Briefings

Initially it is planned that the project meteorologist will make a daily telephone call at about 0800 to Dr. Schleusener at Rapid City to discuss any pertinent problems and to make a status report on IAS equipment and certain NHRE equipment at Grover. A copy of the status form to be used showing the various items requiring a report is included as Appendix C.

6.3 Special NHRE De-Briefing Sessions

IAS personnel will take part in the proposed analytical discussions of selected storms, which has been outlined in the NHRE Program Plan 1972-1976.

When a storm is selected for intensive study, IAS personnel plan to remain in Grover and Cheyenne while the T-28 data reduction is accomplished by the IAS personnel in Rapid City. In this way, radar data can be obtained and analyzed by personnel remaining in Colorado. Also, data on other storms can be gathered if the occasion presents itself.

T-28 data is tentatively planned for shipment back to Cheyenne via XEROX Telecopier or via commercial airlines. The analysis will include preparation of hard copy output of pertinent data gathered by the T-28 during the mission.

7. T-28 DATA SYSTEM

7.1 Instrumentation

The data system on the T-28 includes sensors to measure meteorological and aircraft parameters. These parameters are sampled and recorded at a rate of about 1.6 records per second with each record containing 29 channels of data from the various sensors.

The data recording system on the aircraft is centered around a MetroData Systems DL620A digital magnetic tape recorder, which has been modified to include 9 additional channels of information. Meteorological and aircraft data in analog form are used for inputs to the recorder. These data are processed with a self-contained analog-to-digital converter and multi-plexer, then recorded on 1/4 in four-track magnetic tape cartridges for computer reduction and analysis.

The various parameter channel assignments are given below, and a detailed list of parameters is included as Appendix D:

Channel	Parameter
1 - 2	time
3	ball altimeter
4	indicated air speed
5	VOR
6	WSI altimeter
7	DME
8	manifold pressure
9	Rosemont temperature
10	WSI temperature
11	liquid water content
12	rate of climb
13	regulated 5 volts
14	accelerometer
15 - 17	spare analog
18	audio event
19	event marker
20	spare digital
21 - 24	Joss sensor
25 - 28	rain rate sensor
29	spare digital

7.2 Data Reduction Procedures

Plans call for shipment of the recorded data to Rapid City (RAP) for preliminary reduction and analysis on a PDP-8 computer following a data-gathering mission. This includes transferring the T-28 data to seven-track magnetic tape in an industry-compatible format, in compliance with NHRE requirements.

Normally, the data will be shipped via commercial airlines between Cheyenne (CYS) and Rapid City. Under these circumstances, reduced data can be returned to Cheyenne within 18-42 hours depending upon which flight the data are shipped and the length of time required for reduction in Rapid City. The following Frontier Airlines schedule is given to indicate the possibilities for data shipment.

DEP CYS	ARR RAP	DEP RAP	ARR CYS
0742	1222	1618	1810
1746	2117 or 2209	0625 or 0800	1130

The above times are given in MDT and are the most recently available from Frontier Airlines. All flights between CYS and RAP connect through Denver.

Data arriving in RAP late in the evening can be reduced at night and hopefully returned to CYS early the next morning. Data arriving in RAP at 1222 will be about 18 hours old at that time and conflicts for computer time are likely. Hence, reduced data may be as much as 42 hours old when it is returned to CYS. Normally, data returned to Cheyenne will include photographs of computer-generated displays of selected parameters plus a hard copy printout in engineering units, of any or all of the data recorded by the instrumentation system.

If there is a high probability that NHRE may declare a test case for intensive study, the T-28 will proceed directly to Stapleton Airport following a mission and ship the data from there, so that it will arrive in RAP during the evening. This will enable us to comply with a 24-hour "turnaround" time for reporting data quality to NHRE. In any event, it will be necessary for IAS personnel carrying out the reduction in RAP to call the project meteorologist at Grover the next morning with a data quality report. If problems are apparent in the data, the project meteorologist will request that an additional call be made to the T-28 crew at CYS, so that the problem can be rectified as quickly as possible.

APPENDIX A

National Hail Research Experiment
(Armored Aircraft)

Date ______________

STAH CODE FORM

Grover Time	A/C Time	ALT	Heading	Hail	Ice	Rain	Turbulence Remarks	General Remarks

APPENDIX B

Type of Displays Desired in "Real-Time"

1. Continuously upgraded S-band CAPPI displays of equivalent radar reflectivity factor (Z_e) with contours in 10 dBz intervals from 30 dBz at 1,000 ft intervals from 10,000 ft MSL to storm top, which are controllable by the operator. Since 55 dBz is considered to be near hail threshold at 10-cm wavelength, it would be highly desirable to show this on the CAPPI displays.

2. The path of the T-28 should be shown on the map for the last five minutes, or for a longer time period if specified. This path should be superimposed on the CAPPI displays.

3. An RHI section of Z_e on any section and at any orientation on request of the operator.

4. A 3-dimensional position report of the maximum equivalent radar reflectivity factor (Z_e) of the test case updated at least every 3 minutes. The position of Z_e max should be shown in alphanumeric characters in terms of direction and distance from the present position of the aircraft and bearing and distance from the VOR most applicable to the test case. For example: "140° 15 n mi FR A/C - 120° 40 n mi FR Gill." All altitudes should be given in FT MSL.

5. The past position of Z_e max by showing successive positions of the most intense reflectivity contour at time 0, 0 minus 10 minutes, and 0 minus 20 minutes.

6. Magnetic north should be shown on the computer display with true north being vertically upward.

7. Display on call the position and altitude of other project aircraft with respect to the test case, showing the position for the most recent five-minute time period, expandable to 15-minute periods on request.

8. The actual clock time in digital format should be visible on the console. Also, the data presented on the console should indicate how old the data are, either in terms of presenting the actual clock time at which the (radar and aircraft) data were obtained, or the time lapsed since the observations were taken.

9. Display a 10 x "blowup" of the Z_e data for a smaller portion of the storm being studied.

10. Any of the above displays to be photographed on demand from display console.

Information Desired to be Recorded on 35-mm Film at the Close of an Operational Day for "Post-Analysis"

1. CAPPI displays at 5,000 ft intervals from 10,000 ft to the top of the echo at the time of exit from each pass, as well as 10 minutes before and after each pass to establish cloud trend.

2. RHI slices along and at right angles to the T-28 path at the time of each pass. There should be additional RHI slices available, that are parallel to the RHI slice along the T-28 path, at the discretion of the project meteorologist.

3. Reconstruction of the scope displays with the T-28 position and track for the past 10 minutes from the time of exit from each pass.

4. Scope overlays which include Z_e values with the position and track of each of the other airplanes matched to the position and track of the T-28 airplane to show the correspondence in time and space of the various aircraft. The tracks of these aircraft should be shown for the 15 minutes preceeding the time of exit of the T-28 for its pass.

5. Time-lapse PPI film showing one frame 5 minutes at a constant altitude of 10,000 ft for the entire day's activity. This display should show actual clock time and date as the displays are presented.

6. A hail verification map from storms sampled by the T-28 to give a hail map on a scale the same as the other T-28 data.

7. The capability to recall all displays after the day's activities for review by the IAS pilot and project meteorologist.

APPENDIX C

EQUIPMENT STATUS

NATIONAL HAIL RESEARCH EXPERIMENT
(ARMORED AIRCRAFT)

DATE_____

EQUIPMENT	STATUS	REMARKS
Radars and Communications		
M-33 track (X-band)	Go Lim Out	
M-33 Acq (S-band)	Go Lim Out	
CP-2 (X-band)	Go Lim Out	
CP-2 (S-band)	Go Lim Out	
Computer Display System	Go Lim Out	
123.05 Radio	Go Lim Out	
Other_____	Go Lim Out	
Aircraft		
T-28 (510 MH)	Go Lim Out	
NAV/COM	Go Lim Out	
DL 620	Go Lim Out	
Hail Camera System	Go Lim Out	
Kyle Device	Go Lim Out	
Other_____	Go Lim Out	
_____	Go Lim Out	
_____	Go Lim Out	

APPENDIX D

AIRCRAFT N510MH (South Dakota T-28)

Aircraft Instrumentation

Parameter Measured	Instrument Type	Manufacturer and Model No.	Combined Performance of Transducer, Signal Conditioning and Recording				
			Range	Accuracy	Time Constant	Precision	Resolution
Temperature	Thermistor TS 22	MetroData TVH 26	-30° to +30°C	±0.5°C	0.417 sec	.03°C	.03°C
Temperature	Platinum Resistance	Rosemount 102AU2AP	-30° to +30°C	±0.4°C	0.417 sec	.03°C	.03°C
Liquid Water Content	Hot Wire	Johnson-Williams LWH	0 to 5 gm/m^3	±20%	0.5 sec	.005 gm/m^3	.005 gm/m^3
Indicated Airspeed	Airspeed Transducer CIC 7100	MetroData TVH 26	70 to 350 kt	± 3 kt	0.417 sec	0.35 kt	0.35 kt
Rate of Climb	Variometer	Ball 101A	-6000 to +6000 f/m	±2%	0.5 sec	6 f/m	6 f/m
Position Azimuth	VOR Signal Conditioning	MetroData VT 21	0 to 360°	±2°	0.34 sec	0.36°	0.36°
Position Slant Range	DME Signal Conditioning	MetroData DME Amplifier	0 to 100 nm	±3%	8 sec max	0.5 mi	0.5 mi
Pressure Altitude	Pressure Transducer	Ball EX-210-B	-200 to 30,000 ft	±1%	0.417 sec	30 ft	30 ft
Pressure Altitude	Pressure Transducer CIC 7000	MetroData TVH 26	0 to 30,000 ft	±195 ft	0.417 sec	30 ft	30 ft
Raindrop Spectrum	Impact Transducer	MetroData RR40	0.35 to 7.35mm diameter*	± 1 size class	0.42 sec	1 size class	1 size class
Vertical Acceleration	Strain-gauge Bridge	Statham Instr. Inc. A45-15-350	-15g to +15g	±.1575g	0.417 sec	.0075g	.0075g
			----------	-Planned to be changed for 1972 Project Season			----------
Time	Crystal Controlled Oscillator	MetroData DL620	0 to 24 hrs in seconds	±2 sec/24 hr	---	1 sec	1 sec

* 9 size classes (.35-.5, .5-1.0, 1.0-1.5, 1.5-2.0, 2.0-2.5, 2.5-3.0, 3.0-3.5, 3.5-4.0, 4.0-7.35).

continued

Computed Parameters:

1. Corrected Temperature
2. Buoyancy (Temperature Excess)
3. Change in Aircraft Altitude
4. Virtual Temperature
5. Vertical Velocity of Air

Description of Recording System: MetroData DL620, 20 channel (modified to 29), Digital Recorder. Speed of 48 CH/Sec, uses 60 minute cassettes.

AIRCRAFT N510MH (South Dakota T-28) continued

Aircraft Instrumentation

Parameter Measured	Instrument Type	Manufacturer and Model No.	Combined Performance of Transducer, Signal Conditioning and Recording				
			Range	Accuracy	Time Constant	Precision	Resolution
Manifold Pressure	----------	----------	Planned to be added for 1972 Project Season				
Event Condition	Voltage Level	Lab Fabricated	0 to 9 events	±5 mv	0.417 sec	N/A	N/A
Hail Sensors	----------	----------	Several Under Development for 1972 Project Season				
Sound of Hail Impact on Windshield	Microphone & Tape Recorder	Aiwa TP-1004**	N/A	N/A	±5 sec	N/A	N/A
Liquid Water Content	Laser	NCAR (Kyle)***	1μ to 4 mm 30 size classes	---	1 sec	---	---
Condensed Water	Evaporative Device	NCAR (Kyle)***	5-40 gm/m^3	3 gm/m^3	3 sec	1.5 g/m^3	1.5 gm/m^3
Silver Iodide Nuclei	Coated Rotating Disk	NCAR (Langer)	Instrument will be used on a special test basis to monitor the dispersion of silver iodide released from cloud-seeding rockets.				

Computed Parameters:

1.
2.
3.
4.

Description of Recording System: ** Aiwa TP-1004 Audio Magnetic Tape Recorder. Speed of 1 7/8 in/sec. 2 channels (stero-observer voice, hail impact) uses C-120 cassettes. 60 min/side.

*** Recorder to be provided by NCAR.