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FINAL REPORT ON T-28 ARMORED AIRCRAFT DURING THE PERIOD 1 MAY 1973 - 1 MARCH 1974

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ABSTRACT

A North American T-28 aircraft has been armor plated and specially configured for the penetration of hailstorms. The aircraft has made 110 penetrations of thunderstorms during the summer season of 1972 and 1973.

The aircraft and instrumentation systems have proven to be quite functional in this environment. Most instruments added to the system prior to the 1973 season functioned very well. Additional instrumentation is planned so that the T-28 can better achieve its stated objectives.

Considerable data analysis has been accomplished and a number of reports and articles have been published. Substantial progress has been made on all stated objectives of the T-28 project.

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1. INTRODUCTION

This report covers the period 1 May 1973 to 1 March 1974. The 1973 field season operations are described. New instrumentation on the aircraft is discussed, and its performance during the 1973 field season is evaluated. Research results are presented and a description is given of research currently in progress.

A list of papers and reports completed and in progress during this contract period is included as Appendix A. A breakdown of man months expended on the project is included as Appendix B.

2. OBJECTIVES

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

1. Obtaining measurements of updrafts in regions of hail formation and growth;

2. Determining the composition of high radar reflectivity zones;

3. Studying ice-water budgets in hailstorms;

4. Comparison of data gathered by the T-28 and output from numerical models of hailstone and hailstorm growth being developed under other sponsorship;

5. Providing a measurement platform for the devices designed by Dr. Tom Kyle of NHRE; specifically total liquid water content (Kyle evaporator) and drop-size distributions (Kyle spectrometer); and

6. Use of the T-28 as a platform for other special measurements, such as the Langer ice nuclei device.

3. THE AIRCRAFT

The 1973 field season was the second successful season for the T-28 armored aircraft with the NHRE project. The season consisted of 34 flights, 44.9 flight hours, and 27 thunderstorm penetrations. A complete summary of this activity can be found in Table 1 and in Musil et al., 1973b.

The armored T-28 (Fig. 1) is described in great detail in Sand et al., 1972a; Sand et al., 1972b; and Sand et al., 1972c. The T-28 flew the entire summer with very few mechanical problems and was only down for two days when a metal chip was detected in the engine oil sump by a detector designed for that purpose. No damage was done by the metal piece which had accidently fallen into the engine.

The lightning spikes designed for all the airfoil tips prior to the 1973 season worked quite well in that there were no noticeable lightning strikes to any part of the airframe other than on the lightning spikes and the propeller.

The passive ice depth probe installed on the airframe during the 1972 field season was a valuable aid to the pilot in determining the exact depth of ice on the airframe of the T-28.

TABLE 1

T-28 Research Flight Summary - 1973

Flight Number	Date	Purpose	Research Start	Research Stop	Number of Penetrations
78	30 Jun	Research	1710	1752	4
79	4 Jul	Research	1507	1530	1
80	9 Jul	Research	1721	1805	4
81	21 Jul	Research	1730	1800	1
83	24 Jul	Research	1628	1730	3
87	28 Jul	Research	1635	1805	4
88	29 Jul	Research	1940	2025	4
89	31 Jul	Research	1526	1617	5
90	31 Jul	Research	1725	1745	1

TOTALS

Total Number of Flights	34
Total Aircraft Hours	44.9
Total Number of Cloud Penetrations	27
Total Research Hours	6.8

Fig. 1. Armored T-28 used for thunderstorm penetration.

4. INSTRUMENTATION

Table 2 lists the types of data recorded on each recorder channel with general comments as to its quality. Most of the sensor components worked well during the summer of 1973. The primary data recorder was an exception. This unit gave an unacceptable amount of trouble during the season. The recorder has reached the end of its useful life as a reliable component and is being replaced.

The entire data system is discussed in the previous annual reports and is the subject of a paper by Johnson (1974). His paper describes in detail the unique features of the data system which permitted quick data turnaround through a computer in Rapid City while the aircraft was on location in Cheyenne. This system worked quite well and enabled the crew operating the aircraft and the data system in the field to make an immediate diagnosis of any problem with the system, and get a very rapid "first look" at the data.

New equipment installed prior to the 1973 season is described and an evaluation of its performance is given. Additional equipment which we feel should be installed prior to the next field season is described. This new equipment will better enable the T-28 project to attain its stated objectives.

4.1 New Equipment Installed Prior to the 1973 Season

4.1.1 Rosemount icing rate probe

A Rosemount icing rate probe was added to the system to permit a quantitative measurement of the icing rate in the region of hail formation and hail growth. Data from this device gives a better understanding of the availability of supercooled water for hailstone growth.

The icing rate probe proved to be a useful piece of equipment and functioned well. The device was not able to give quantitative measures of the icing rate due to problems in the collection properties and velocity of the probe but does provide valuable information on various cloud characteristics important to certain types of hail growth (Musil and Sand, 1974).

4.1.2 Foil impactor

A foil impactor was added to the T-28 system to permit counting and sizing ice and liquid particles between 0.32 and 20 mm diameter. The device provided usable data on 7 of the 9 research flights and on 20 of the 27 penetrations. Due to the laborious task of reducing foil data only 9 of the 20 penetrations have been reduced.

TABLE 2

T-28 Data

General Quality Summary - 1973

Channel	Parameter	Quality
1-2	Time	Always good, synchronized daily with Grover
3	Ball Altitude	Generally good, within 3-4 mb
4	Indicated Airspeed	Very good
5	VOR	Good, within 2°
6	Rosemount Ice Rate	Very good
7	DME	Very good, but breaks lock in cloud frequently
8	Manifold Pressure	Good, some spikes in data
9	Rosemount Temperature	Good, some spikes in data
10	WSI Temperature	Good
11	J. W. Liquid Water	Good
12	Rate-of-Climb	Good, zero bad, between ± 3 m sec^{-1}, it sticks at -3 m sec^{-1}
13	Regulated 5 volts	Very good
14	PRT-5 Temperature	Very noisy, requires filtering, unusable
15	Kyle Lyman-Alfa (Total Water)	Good, zero drift due to deposits on window
16	Kyle V_p (Total Water)	Good
17	Event Code	Very good
18	+G Accelerations	Unacceptable

TABLE 2 (Continued)

Channel	Parameter	Quality
19	-G Accelerations	Unacceptable
20	Spare	--
21-24	Rain Rate 40	Unacceptable
25-33	Hail Sensor	Development not complete
34-49	Spare	--
--	Hail Sound	Very good
--	Hail Camera	Unusable, faulty equipment
--	Cloud Camera	Good
--	Foil Impactor	Very good
--	Precipitation Sampler	Very good
--	Pilot's Voice Recordings	Very good
--	Radio Voice Recordings	Very good
--	Primary Data Recorder	Unacceptable
--	Redundant Data Recorder	Very good

A shortcoming of the data is that it is only possible to distinguish all liquid particles from those which are partially or completely ice. Any particle that has any ice at all is classified as ice. These particles frequently contain a sizable fraction of water (observed by the pilot) and would normally be classified as slush if there was any way to make this distinction. Foil impactor analysis is the subject of a Master's thesis by Mr. Ed May and will be published as a technical report.

4.1.3 Barnes PRT-5

The Barnes PRT-5 infrared radiometer was installed on the T-28 to gather temperature data within a few meters of the aircraft and eliminate the problems inherent to other temperature sensors of wetting and freezing, etc. The device was furnished by NCAR and installed on the T-28 but the data proved to be so noisy that it was impossible to filter out the temperature data.

4.1.4 Four-channel voice/data recorder

A Hewlett-Packard four-channel data and voice recorder was added to the T-28 system to record (1) pilot's comments, (2) hailstone impact noise on the windshield, (3) incoming radio transmissions, and (4) redundant meteorological data. The redundant data channel was used to duplicate the data tape from the DL-620 data recorder and permitted transmission of the data via telephone link directly to the computer at Rapid City for a quick check of the data quality and a quick look at the data. This recorder worked very well with no significant problems.

4.1.5 Hail camera

A small camera and strobe system was developed by NHRE personnel for use on the T-28 to attempt to make a photographic recording of the presence and number of small hailstones. The device was installed on the T-28 and used on numerous occasions during the 1973 season but the results were not usable due to a faulty component in the strobe system which resulted in insufficient light to properly expose the small hailstones for photographing.

4.1.6 Cloud camera

A super 8-mm, automatic exposure control camera was installed on the T-28 to record the outward appearance of the clouds being penetrated by the T-28 at the levels of penetration. This system functioned well during the 1973 season taking pictures of clouds prior to and after penetrations.

4.1.7 Event code

With the addition of a number of momentary or single event components to the data system, an expanded event code system was needed to permanently record these events as part of the data record. The event code system removed the requirement for the pilot to record these events manually. The occurrence of certain events are automatically and precisely time located in the total data system output for later analysis. The system worked extremely well.

4.1.8 Precipitation sampler

A device to capture precipitation samples (mouse trap) was designed and built by NCAR for addition to the T-28 instrumentation system. The device samples 2.4 m^3 of air per sample during each of its three sampling events per flight. The device functioned quite well during the 1973 season, providing NCAR personnel with several samples for laboratory analysis.

4.2 New Equipment Planned for the Next Field Season

Based on the past two years' experience we have identified a number of improvements to the T-28 system that will better enable us to fulfill our stated objectives. This new equipment is needed to give the T-28 system additional capability and reliability in its unique role of gathering data from the interior of thunderstorms.

4.2.1 Recording system

Purchase of a ruggedized Precision Instruments Model 1387 seven-track magnetic tape recorder and a Monitor Labs Model 9100 multiplexer unit has been approved and the equipment has been ordered. This system will be capable of recording 30 channels of digital data and 24 channels of analog data and should provide an excellent recording capability for the T-28.

4.2.2 Temperature

Measuring temperature inside a cloud has proven to be a formidable problem. Direct sensing elements are subject to errors due to wetting and freezing. The reverse flow concept of temperature measurements appears to hold the most promise for accurate measurements. The unit we have used for the past two years contains a thermistor sensing element and is subject to a substantial drift from day to day and even on a given flight. The instrument has quite good relative accuracy (within about 0.5C) during a given penetration but its absolute accuracy is subject to an error of several degrees.

NCAR Flight Facility is currently building a new temperature sensor for the T-28 which should overcome the short-term temperature drift problem and the accuracy problem by using a platinum sensing element in a reverse flow housing.

4.2.3 Updrafts

The Ball variometer which has been used for the past two years is subject to sticking at -3 m sec^{-1} when the true rate-of-climb value is between ±3 m sec^{-1}. The unit is currently at the manufacturer's plant and will be repaired if possible and if not, it will be replaced.

4.2.4 Accelerometer

The accelerometer in the T-28 instrumentation package will be repaired or replaced with more precise transducers. They are designed to measure vertical accelerations in the shear zones and severe turbulence within an active hailstorm. They may also be used to add better definition to updrafts.

4.2.5 Laser hail sensor

The laser hail sensor is designed to count and size hailstones passing through a sheet of laser light approximately 1/3 m^2 in area. Since the T-28 flies at approximately 100 m sec^{-1}, the sampled volume is about 33 m^3 sec^{-1}. The device will have a resolution of approximately 1 mm diameter when sizing the hail.

Work is continuing on this device at the South Dakota School of Mines and Technology and it should be ready to acquire data prior to the next field season. The development of this device is the subject of a Master's thesis scheduled for completion in May 1974 by Mr. Bill Shaw.

4.2.6 Ground power unit

A regulated 28 volt ground power supply unit will be purchased to provide a stable 28 volt power source for ground operations of all instrumentation. The previous ground power supply had caused numerous problems with the instrumentation because of fluctuations in its power level.

4.2.7 Redundant recording system

Even with the high reliability expected from the new recording system, we intend to record all data on another independent system.

This system will consist of a multiplexer unit, an independent clock, and our present four-channel Hewlett-Packard recorder. The remaining three channels will be used as previously for audio inputs.

We feel that data gathered by the T-28 system is of such importance and difficulty to acquire that the totally redundant data systems are more than justified.

4.2.8 Pressure transducer

The Ball EX-210-B pressure transducer used in the past is nonlinear and is not temperature compensated. It is only accurate to about 3-4 mb. This unit needs to be replaced with the Rosemount series 1301 temperature controlled pressure transducer to acquire a stated accurate of 0.1% full scale. Accurate and precise pressure measurements may be differentiated to solve for vertical velocity and combined with accelerations to look for pressure deficits.

4.2.9 Aircraft heading

A synchro-to-DC converter will be acquired to permit recording the aircraft heading from the gyro-stabilized compass system currently used on the aircraft. This will provide one of the four parameters required to compute horizontal wind inside the cloud. The remaining three parameters, true airspeed, track, and ground speed, are currently being recorded.

4.2.10 Encoding altimeter

A new Federal Aviation Agency regulation requires that we have an encoding altimeter prior to 1 July 1975 to operate at or above 14,500 ft MSL in controlled airspace.

5. FIELD OPERATIONS

The field operations went extremely well during the summer field season. There were 27 thunderstorm penetrations made during the summer season which are summarized in Table 1.

The rapid recall system was perfected during the 1973 field season and functioned very well for the entire summer. This system used the data tape recorded on the redundant recorder and played it into a modem, through a telephone link, another modem and into a PDP-8 mini-computer and a CDC 3400 computer at Rapid City for reduction and analysis. Analog traces of the various recorded parameters were then sent back to the field crew in Cheyenne via a telecopier. This system provides the field crew with the capability of looking at the data in a matter of hours after the completion of a flight to determine data quality. A sample of the data received from this system is included in Fig. 2.

Substantially greater induction system icing was experienced during the 1973 season than was experienced during 1972. This is felt to be a result of the more selective procedures used to determine the penetrations made during this field season. The meteorologist at Grover and the pilot both felt that the storms penetrated during the 1973 season were considerably more severe than those previously penetrated. The induction icing caused considerable problems with keeping the engine running smoothly but, with the addition of carburetor heat the engine did continue to run, even though not very smoothly. No scheme has yet been developed to alleviate this problem since it is due to icing over the protective grates across the carburetor intake. There is no way to heat this area and no way to put deicing fluid on it to prevent the buildup of ice.

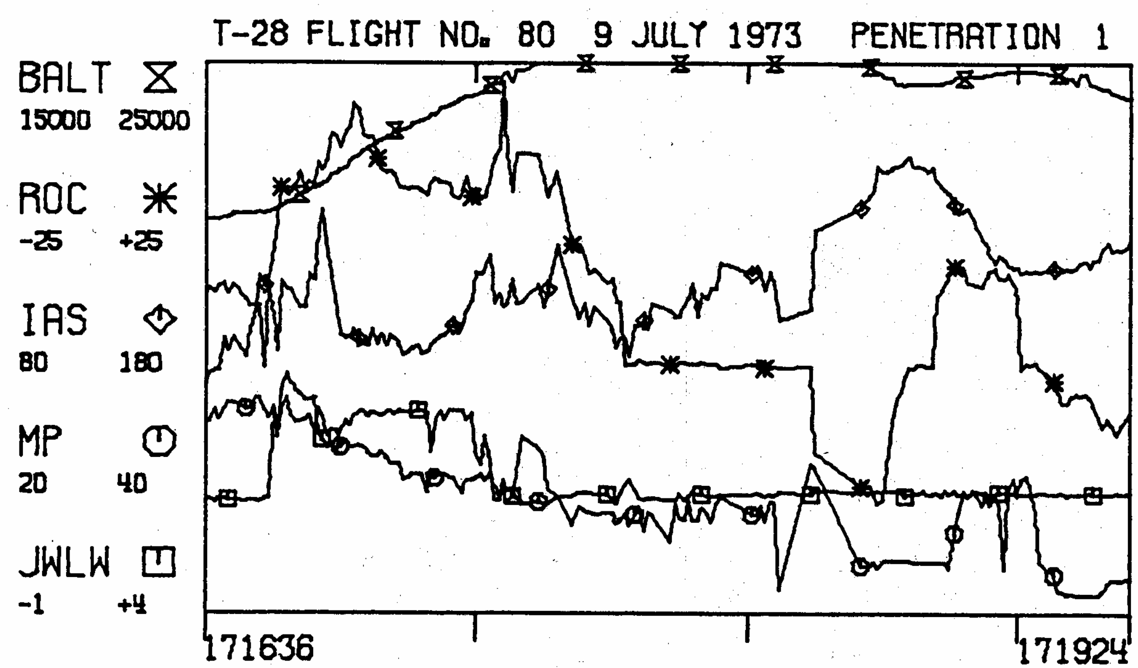

Fig. 2. Mini-plots used for a quick look at the data and as a data quality check.

6. RESEARCH PROGRESS

Research associated with the T-28 project is centered around attaining the stated objectives (Section 2). The progress to date will be described in relation to these objectives. Some potential research has been delayed or restricted in scope due to the paucity of radar data for the 1972 and 1973 project season.

6.1 Obtaining Measurements of Updrafts in Regions of Hail Formation and Growth

Multiple areas of updraft are found on certain penetrations made in 1972 (Musil et al., 1973a). The form of the updraft profile is reported to match the axially symmetric jet model best by Kyle and Sand (1973b).

Dr. Kyle is analyzing turbulence and diffusion data derived from the T-28 project.

A limited number of cases exist where the track of the T-28 as recorded by the M-33 radar appears to be curved, suggesting an internal cyclonic rotation of the cloud system. This is being studied further and a system to record aircraft heading is planned for the T-28 to expand these studies of horizontal and vertical winds within a thunderstorm.

Cold air downflow along the edges of thunderstorms has been measured by Sinclair (1973) and in some cases is noted in the T-28 data. Work is continuing in this area and a better temperature measuring device is planned to permit the T-28 system to measure this phenomenon.

As part of Mr. Wayne Sand's Master's degree thesis, updrafts are being related to the high reflectivity zones. Expansion of this work is planned as soon as more radar data become available.

Work is in progress to relate the climatology of updrafts to hail occurrence based solely on the T-28 data. In this study an attempt is being made to relate the strength and size of the updrafts to the occurrence and size of the hail based solely on the T-28 updraft data and hail observations made during penetrations.

6.2 Determining the Composition of High Radar Reflectivity Zones

This is the subject of Mr. Sand's Master's degree thesis which is scheduled for completion in early May 1974. This thesis will be submitted to NHRE as a technical report. The study compares such things as: hail, updrafts, liquid water content, turbulence, icing, and lightning to the location of the high reflectivity zones.

As a result of Mr. Sand's work considerable effort has gone into the development of usable computer generated radar displays. The NHRE staff has developed a program to produce CAPPI's at any level in the cloud. The IAS staff has developed a program to produce vertical sections along the path of the T-28. An example of both these outputs can be seen in Figs. 3 and 4.

The T-28 data are available in the form of color analog traces for easy use in the comparison of it with the radar data since they are produced with the same scale. A sample of the analog traces of the T-28 data is shown as part of Fig. 3 where the one to one comparison of the radar data and T-28 data can be seen.

6.3 <u>Ice-Water Budgets in Hailstorms</u>

Mr. Ed May is preparing a Master's thesis using the data from the foil impactor to study particle distribution in hailstorms penetrated on 9 and 31 July 1973. This work is scheduled for completion in early May 1974 and will be submitted to NHRE as a technical report.

An article on the Rosemount icing rate probe (Musil and Sand, 1974) has been submitted to <u>Atmospheric Technology</u>. The icing rate probe data can be used to make general comments relative to the supercooled liquid water content in the thunderstorms being penetrated.

Dr. Tom Kyle of the NHRE staff has designed and built three devices that are also used to make measurements relative to the ice-water budgets of thunderstorms.

The total water content probe has been used for the last two summers and has provided some data relative to the total water content of thunderstorms penetrated (Kyle and Sand, 1973a). Locally high concentrations of liquid water have been found with horizontal extents too small to be detected by the radar.

A droplet spectrometer designed by Dr. Kyle has been carried on the T-28 for the 1972 and 1973 seasons in an attempt to measure droplets in the 80 to 320 μ diameter size range. The droplet spectrometer uses the principle of light extinction in a sheet of laser light to count and size droplets. To date this device has produced no usable data but we feel that measurements in this size range are required for the study of the total ice-water budget.

The third device designed by Dr. Kyle for use on the T-28 is the precipitation sampler (mouse trap). This device has been described earlier in Section 4.1.8. The data obtained during 1973 are currently under analysis by scientists at NHRE and the University of Wyoming.

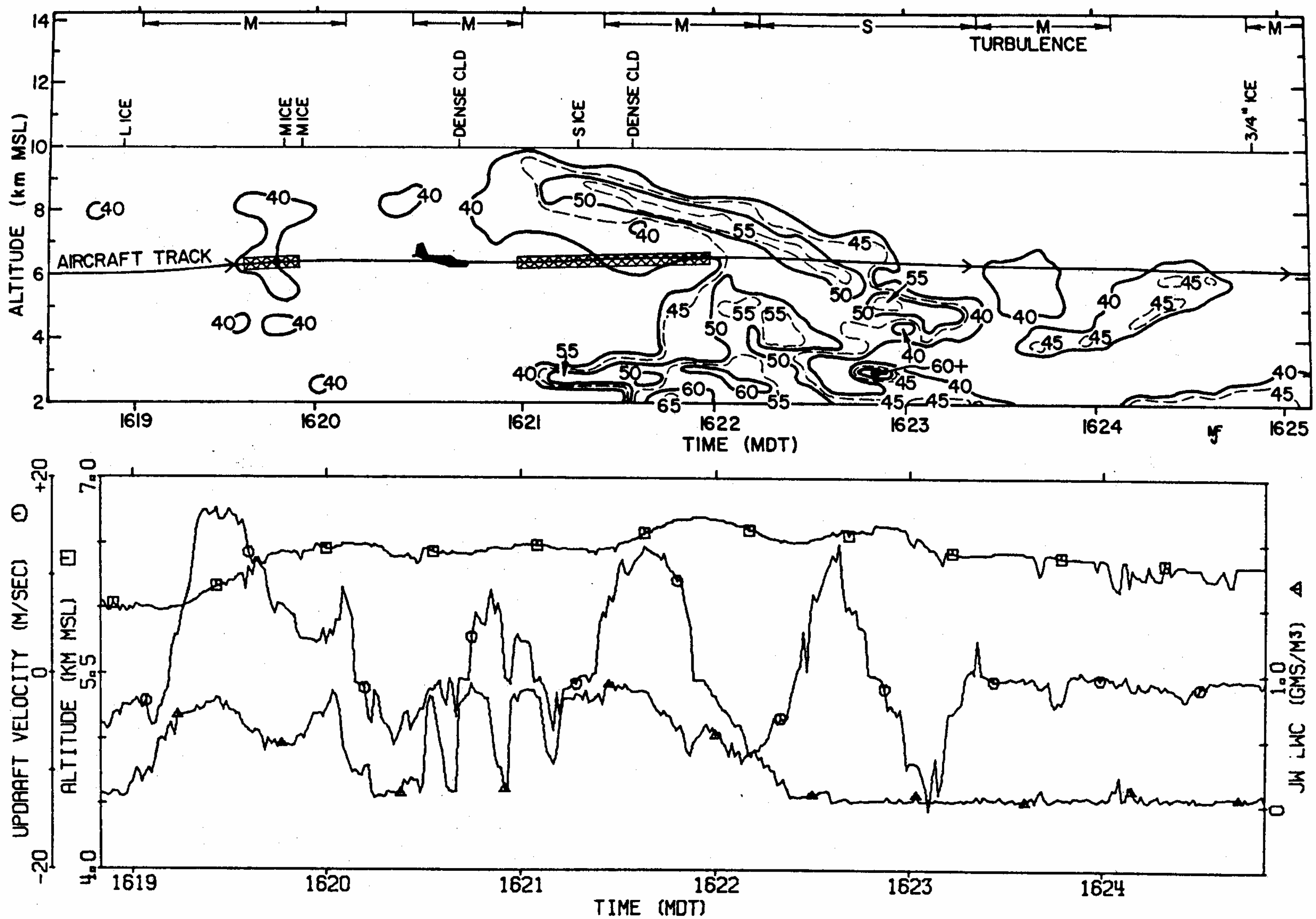

Fig. 3. 22 July 1973 - Penetration 2. Vertical section aircraft data and pilot's observations.

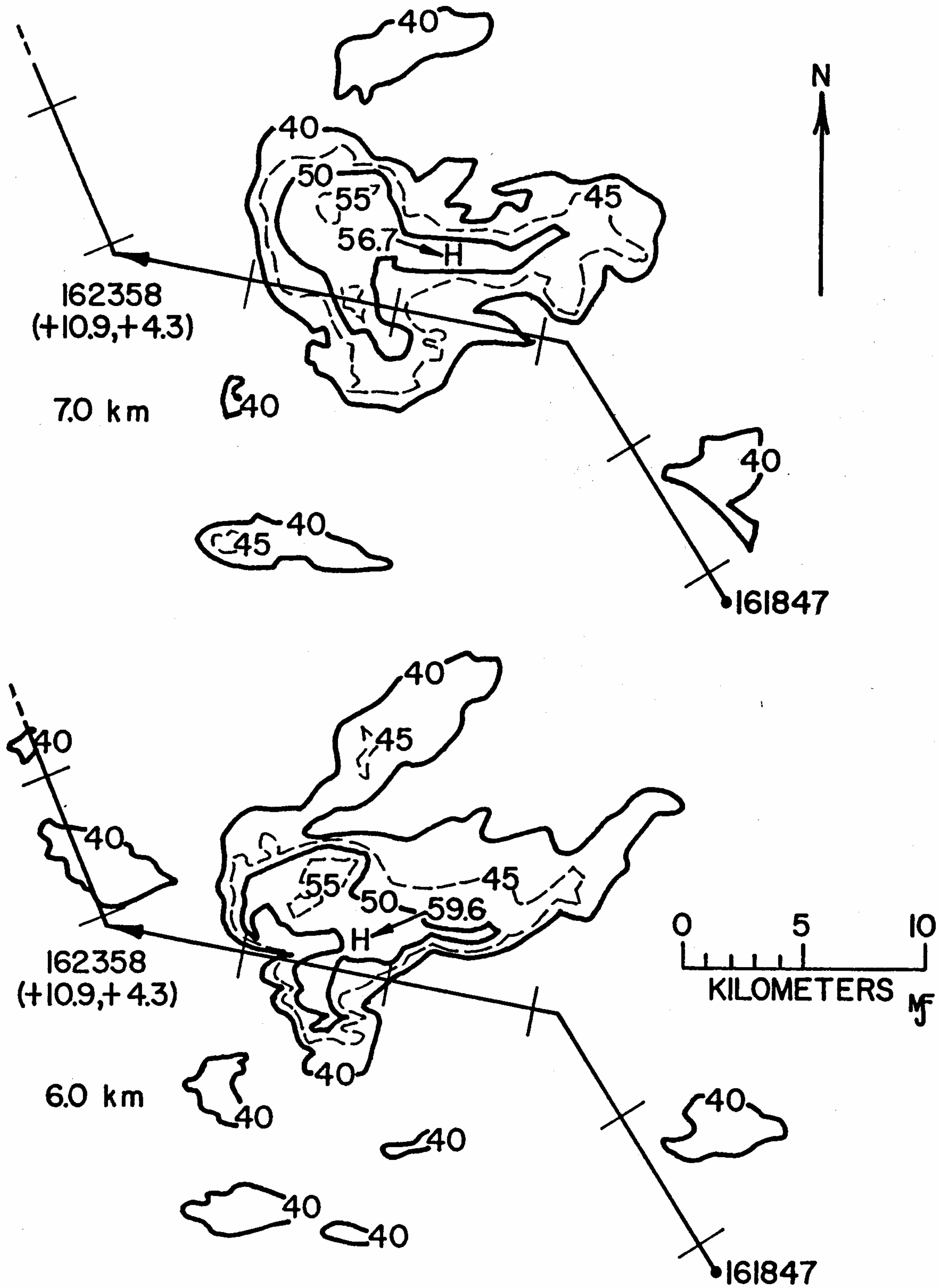

Fig. 4. 22 July 1973 - Penetration 2. CAPPI displays at 5 and 6 km MSL along T-28 track.

6.4 Comparison of Data Gathered by the T-28 and Output from Numerical Models

Some initial comparisons were made by Musil et al., 1973a. This work is continuing in an attempt to compare the results of the Hirsch (1971) model updrafts with those measured by the T-28. The comparisons made to date indicate favorable agreement. This work requires more extensive use of 10-cm radar data to obtain estimates of cloud tops.

Kyle and Sand 1973b compared the measured updraft profiles to the Guassian, the polynomial and the axially symmetric jet models of updraft profiles. All fit reasonably well with the axially symmetric jet model fitting best.

Since the T-28 measures the presence and location of hail we are attempting to correlate the radar hail signals being generated by the CPR-2 and CHILL radars (Eccles, 1973) with the actual hail encounters by the T-28. Requests have been sent out to personnel dealing with analysis of the CPR-2 and CHILL radar data proposing that we make these comparisons. Completion awaits response to these requests.

6.5 Provide a Measurement Platform for the Devices Designed by Dr. Kyle

This work has already been discussed under Section 6.3.

6.6 Use the T-28 as a Platform for Other Special Measurements

The Langer ice nuclei device was used successfully during the summer of 1972 to detect silver iodide crystals in clouds being penetrated with the T-28. Dr. Langer of the NCAR staff analyzed these data and will use any data gathered in the future to determine the presence of silver iodide in the clouds penetrated with the T-28. This device is very critical to the study of seeded clouds with the T-28 since it is germane to the problem of cloud seeding to verify the presence of silver iodide at the critical levels in the clouds being seeded.

The T-28 has been used as a cloud seeding platform to directly place the seeding material into the cloud at the -7C level just ahead of the high radar reflectivity zone and into the updrafts at that level. Analysis of the one case seeded on 29 July 1973 is awaiting the availability of radar data. The indication to date from this case is that it appears that more lightning was developed as a result of the seeding. This observation was made by both the pilot inside the cloud and Dr. Knight from a point on the ground ahead of the storm. Silver iodide samples were also gathered by the Desert Research Institute in precipitation falling from this cloud.

7. PERSONNEL CHANGES

Mr. William G. Myers left the IAS staff on 30 June 1973. A portion of Mr. Myers' time was devoted to electrical engineering work on the T-28 system.

Mr. Jerry L. Halvorson joined the IAS staff as a full-time programmer on 1 January 1974.

8. SUMMARY AND CONCLUSIONS

1. The T-28 operated successfully during the 1973 summer research season gathering meteorological research data from the interior of thunderstorms.

2. With few exceptions the instrumentation added to the T-28 system prior to the 1973 season functioned very well. The recording system on the T-28 proved to be the largest single source of problems with the data system. A new recorder has been purchased to rectify this problem.

3. Based on experience from the last two field seasons, a list of new equipment required to study areas of critical interest inside the thunderstorm has been developed. Acquisition of the recommended list of new or improved instrumentation will better enable the T-28 to achieve its stated goals.

4. Progress has been made toward the achievement of the stated goals of the T-28 project.

   a. Multiple updrafts have been detected in a single thunderstorm cell.

   b. The updraft profile best matches an axially symmetric jet model.

   c. The high radar reflectivity zones have been related to such things as hail, updrafts, liquid water content, turbulence icing and lightning. Detailed results are forthcoming in a technical report.

   d. Ice-water droplet distributions have been related to updrafts. Detailed results are forthcoming in a technical report.

   e. Model comparisons made to date show formidable agreement with the Hirsch model.

   f. Considerable specific data have been gathered for NHRE scientists by the addition of special sensors to the T-28 data system.

ACKNOWLEDGMENT

The information upon which this report is based was obtained during the National Hail Research Experiment activities organized by the University Corporation for Atmospheric Research and sponsored by the National Science Foundation (Prime Contract Number NSF-C460, Subcontract Number NCAR 182-71).

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Sinclair, P. C., 1973: Severe storm air velocities and temperature structure deduced from penetrating aircraft. Preprints, Eighth Conf. of Severe Local Storms, Denver, Colorado, 25-30.

APPENDIX A

Articles and Reports Published or Submitted for Publication

Annual Report	Sand, W. R., R. A. Schleusener, and D. J. Musil, 1973: Final report on T-28 armored aircraft during the period 1 May 1972 - 1 May 1973. Institute of Atmospheric Sciences, Report 73-11, South Dakota School of Mines and Technology, Rapid City, South Dakota, 23 pp.
Operations Report	Musil, D. J., W. R. Sand, and R. A. Schleusener, 1973: Summary of T-28 field operations - 1973. Report 73-14, Institute of Atmospheric Sciences, South Dakota School of Mines and Technology, Rapid City, South Dakota, 7 pp.
WMA Article	Sand, W. R., R. A. Schleusener, and D. J. Musil, 1973: Observed updrafts and hail inside a thunderstorm. J. Wea. Mod., 5, 1, 24-29.
Science Article	Kyle, T. G., and W. R. Sand, 1973: Water content in convective storm clouds. Science, 180, 1274-1276.
Severe Storms Conference Paper	Kyle, T. G., and W. R. Sand, 1973: The vertical velocity profile in thunderstorm updrafts. Preprints, Eighth Conference on Severe/Local Storms, Denver, Colorado, 39-40.
Severe Storms Conference Paper	Musil, D. J., W. R. Sand, and R. A. Schleusener, 1973: An interior view of a hailstorm near 20,000 ft. Preprints, Eighth Conference on Severe Local Storms, Denver, Colorado, 35-39.
JAM Article	Musil, D. J., W. R. Sand, and R. A. Schleusener, 1973: Analysis of data from T-28 aircraft penetrations of a Colorado hailstorm. J. Appl. Meteor., 12, 1364-1370.

Articles and Reports in Progress

Master's Thesis	Sand, W. R., 1974: Observed composition of the high radar reflectivity zones in hailstorms. Scheduled for completion in May 1974.

Master's Thesis	May, E. L., 1974: Analysis of foil impactor data from armored aircraft penetrations of hailstorms. Scheduled for completion in May 1974.
Master's Thesis	Shaw, W. S., 1974: Design considerations of an airborne optical hail detector. Scheduled for completion in May 1974.
Cloud Physics Conference Paper	(Icing Data) Abstract submitted.
Cloud Physics Conference Paper	(Foil Data) Abstract submitted.
Aerospace & Aeronautical Meteorology Conference Paper	(Turbulence Data) Abstract submitted.
Weather Modification Conference Paper	(Multiple Updrafts and Updraft Locations) Abstract submitted.
Atmospheric Technology Paper	Musil, D. J., and W. R. Sand, 1974: Use of the Rosemount icing rate probe in thunderstorm penetrations. Accepted for publication in <u>Atmospheric Technology</u>.
Atmospheric Technology Paper	Johnson, G. N., 1974: Distinctive features of the T-28 data system. Accepted for publication in <u>Atmospheric Technology</u>.
<u>AMS Bulletin</u> Article	Sand, W. R., and R. A. Schleusener, 1974: Development of an armored T-28 aircraft for probing hailstorms. Submitted for possible publication in the <u>Bull. Amer. Meteor. Soc.</u>

APPENDIX B

List of Personnel Associated with NHRE Project
1 May 1973 - 28 February 1974

Name	Title	Months Worked Under Referenced Contract
Professional		
R. A. Schleusener	Director	1.90
Jerry Halvorson	Junior Research Engineer	1.57
John H. Hirsch	Research Meteorologist	.77
Gary N. Johnson	Junior Research Engineer	5.31
Dennis J. Musil	Research Meteorologist	6.00
Wm. G. Myers	Research Engineer	1.53
Garth Peterson	Mathematician Programmer	2.13
Wayne R. Sand	Pilot	9.02
Paul L. Smith, Jr.	Head, Engineering Group	.41
		28.64
Technical Staff		
Rudolph D. Flohr	Electronics Technician	9.12
Jon Leigh	Aircraft Mechanic	8.42
		17.54
Graduate Students		
Edwin L. May		7.09
William S. Shaw		6.75
		13.84
Undergraduate Students		
Andrew Furiga		1.04
Jerry Halvorson		4.80
Kenneth E. Jasper		.86
Ronald E. Klein		.45
		7.15
Secretaries		
Joie Robinson		.83
Carol Vande Bossche		.20
Ramona M. Young		.20
		1.23
Total man-months		68.40