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NCAR CONVECTIVE STORMS DIVISION 1978 FIELD PROGRAM - T-28 ARMORED AIRCRAFT WORK PLANS

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1. INTRODUCTION

The Institute of Atmospheric Sciences (IAS) of the South Dakota School of Mines and Technology will provide its armored and instrumented T-28 aircraft for participation in the 1978 field experiments of the Convective Storms Division (CSD), National Center for Atmospheric Research (NCAR). This is a continuation effort under Subcontract No. NCAR 182-71. The overall program is sponsored by the National Science Foundation (Grant NSF C760) and is under the direction of NCAR.

Work to be carried out during 1978 emphasizes gathering of observations associated with the initiation of precipitation in convective clouds. Some mature thunderstorms/hailstorms may also be penetrated to gather additional information and particularly to check the performance of modifications recently made to the hail spectrometer. Procedures to be followed in these data gathering activities are set forth in Section 4. The main purpose of this work is to answer questions relating to the initiation and growth of precipitation, and thus further the understanding of convective storms.

The configuration of the T-28 instrumentation will be essentially the same as that used in the 1976 field season. Because of this year's emphasis upon precipitation initiation, the Cannon particle camera will be given first priority over the hail spectrometer (T-28 limitations preclude simultaneous installation of these two instruments). Section 5 describes the instrumentation and the data to be recorded.

The "quick look" reduction technique for T-28 data used so successfully in 1976 will be continued in 1978. Its worth in uncovering instrumentation problems and providing a look at the data while the events are still fresh in the experiment team's mind is firmly established.

2. OBJECTIVES

The overall objective of the T-28 participation in the 1978 CSD program is to gather data within and in the immediate vicinity of northeast Colorado convective clouds with minimal restrictions on storm penetration capabilities. Analysis and interpretation of these data in conjunction with other aircraft, radar, surface, and related data gathered by other experiment participants will lead to a more complete understanding of the processes of precipitation development within convective clouds, with a view toward applications to both hail suppression and rain augmentation.

The specific IAS objectives for the 1978 CSD field experiment include:

1. Investigation of hydrometeor characteristics and size distributions in convective clouds at the time of first radar echo development and during the formation and growth of precipitation.

2. Identification of the location and microphysical structure of embryo growth regions.

3. PERSONNEL

The 1978 field operations will be carried out by the following individuals:

Name	Function
Dennis J. Musil	Project Meteorologist
John Prodan	Pilot
Gary N. Johnson	Engineer
Jon E. Leigh	Aircraft Mechanic/Technician
Jerry L. Halvorson	Computer Programmer
Carlton P. Laco	Technician

The project meteorologist will be located at the NCAR field site at Grover, Colorado, and the computer programmer will remain in Rapid City, South Dakota. The other team members will be located at Laramie, Wyoming, with the T-28 aircraft operating out of the University of Wyoming hangar facilities there.

The project leader is Dr. Paul L. Smith, Jr. He, along with Dr. Arnett S. Dennis and Mr. Dennis J. Musil, are co-principal investigators for the studies carried out under this research program.

4. CLOUD PENETRATION PROCEDURES

4.1 General Comments

The general T-28 flight procedure for the 1978 first echo experiments will consist of making repeated cloud penetrations at a flight level near 18,000 ft (5.5 km) MSL, where the ambient temperature is about -10°C. The penetrations will begin when the sailplane N9929J passes through altitude 21,000 ft (6.4 km). As the sailplane ascends in the updraft, the T-28 penetration altitude can be increased as long as 3,000 ft (0.9 km) separation is maintained.

For penetrations of more intense convective systems where the sailplane is not present, the T-28 will operate at flight levels near 20,000 ft (6.1 km) MSL, with ambient temperatures of about -15°C. The objective then will be to penetrate the major inflow area and the high reflectivity region (or the edge of it, if safety restrictions require) of the storm.

Safety is of primary importance in the penetration procedures designed for the T-28. In matters of flight safety, the T-28 pilot has the final decision. From past experience, avoiding the portions of the storm with reflectivity factors greater than 55 dBz along the flight path at or above the level of penetration has resulted in no encounters with hail larger than the size for which the aircraft's protection has been tested. Such high reflectivities are not anticipated in the first echo experiments, but this limit will be adhered to in any mature storm penetrations. The penetrations will be directed by the project meteorologist from the Grover operations room. Except for adjustments necessary because of the convective system's vagaries, the flight procedures outlined below will generally be followed. Real-time adaptation to unforeseen or dynamic situations may be a valuable capability, but it cannot take the place of sound thorough planning.

Because of the emphasis this year upon first echo experiments and studies of precipitation initiation, the T-28 will probably be launched more frequently than in the past, with a resulting increase in "airborne standby" status. To maximize the useful penetration time, T-28 takeoff is planned for only about 30 minutes before the expected beginning of a first echo experiment. This will be about an hour later than the NOAA/NCAR sailplane (29J) takeoff and about 15 minutes later than the Wyoming Queenaire (10UW). Notification for takeoff will come from the CSD operations director at Grover and be relayed to Laramie by the project meteorologist using radio communications.

It is expected that all of the research aircraft fleet will be airborne simultaneously during the first echo experiments. Therefore, close coordination of the cloud penetrations is an absolute requirement. The sailplane, the T-28, and the Wyoming Queenaire will be in the cloud simultaneously, stacked at intervals of not less than 3,000 ft (0.9 km). Flight safety under these conditions is a critical factor and all pilots, especially those "in cloud," must be aware of the other aircraft locations.

4.2 Specific Procedures

Different penetration procedures are planned depending upon the basic research objective of each mission. Under the primary emphasis on first echo and precipitation formation data, it is anticipated that the clouds of interest will be of two basic types: 1) isolated cumulus congestus; or 2) feeder clouds adjacent to existing storms. Figure 1 shows a profile of the proposed "Figure 8" penetration track to be followed by the T-28 (and other powered penetration aircraft). For the isolated clouds, one leg will be along the direction of estimated cloud motion, as determined from the 16,000 ft (4.9 km) wind direction, with the other leg crosswind. For the feeder clouds, a similar pattern will be used except that the penetration legs will be aligned so as to prevent entry into the more intense areas of the storm (Fig. 2). Under these circumstances, the penetrations will probably not align with or be perpendicular to the motion of the cloud/storm.

For any mature storm studies, the convective systems will be one of three basic types: 1) quasi-steady-state storms; 2) multicell storms; or 3) line storms. Past field work indicates that the majority of storms in the experiment area will be of the multicell type, although some may take on the characteristics of a steady-state storm for a while. Furthermore, line storms usually contain cells which are multicellular or steady-state in nature. This makes real-time identification of the storm type a very difficult task in most cases. Therefore, decisions concerning flights to be undertaken will require close coordination between the operations director and the T-28 project meteorologist.

Penetration tracks for mature storms will typically be as shown in Figures 3 and 4. Consideration of the instrumentation carried on the T-28 will be a factor in deciding between the penetration procedures shown in Figure 4. The solid track would be more suitable when the hail spectrometer is carried, because of the chance of encounters with higher reflectivity and larger particles. The dashed track would be more suitable when the Cannon camera is carried because it has a much smaller size detection limit and can provide information on the phase of particles in the initial phases of growth. Evidence suggests the importance of following the evolution of the hydrometeors closely around the time of first echo development. The dashed track would also be followed if the reflectivity along the solid path is too high, regardless of which equipment is being carried.

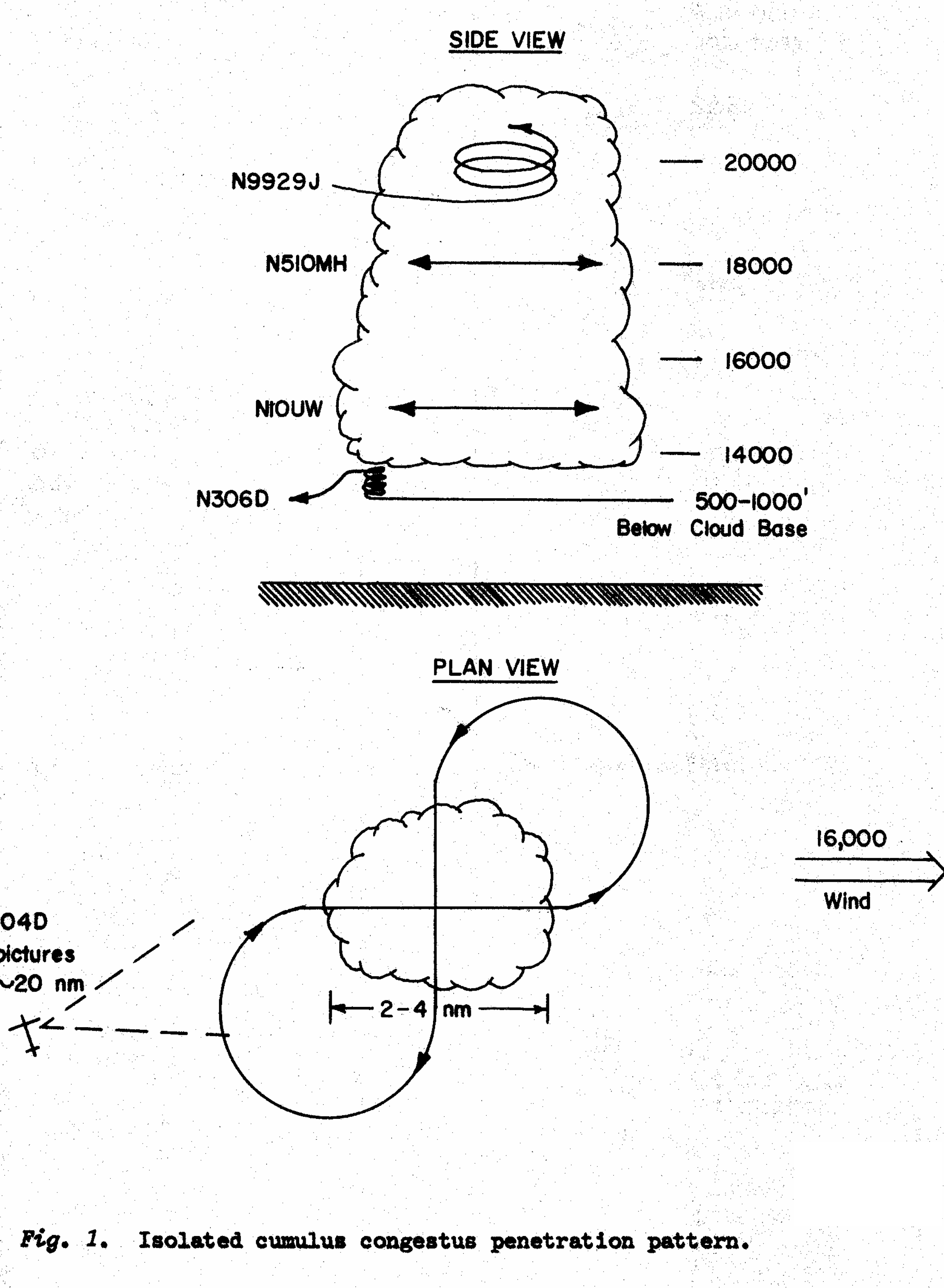

Fig. 1. **Isolated cumulus congestus penetration pattern.**

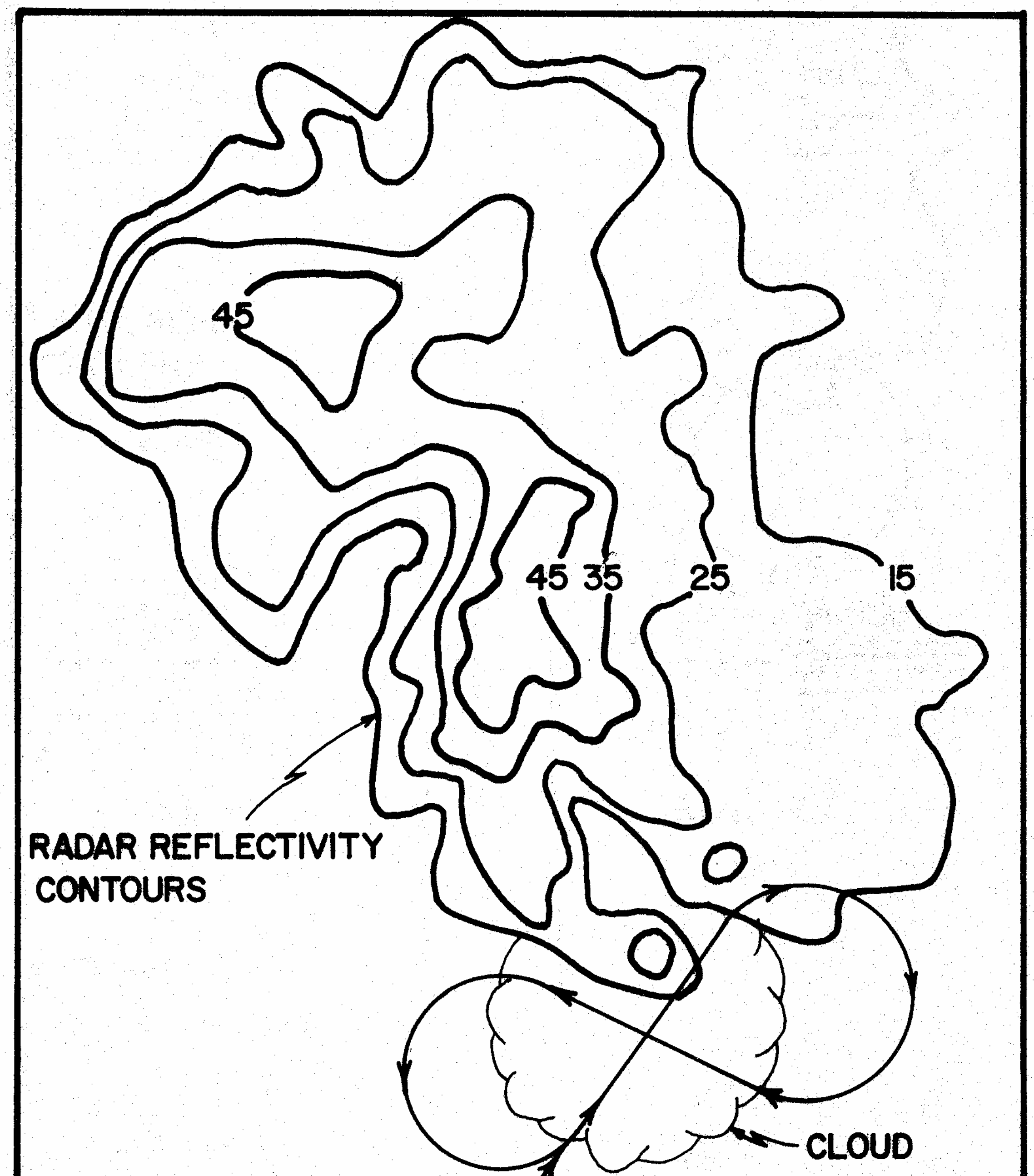

Fig. 2. **Feeder cloud penetration pattern.**

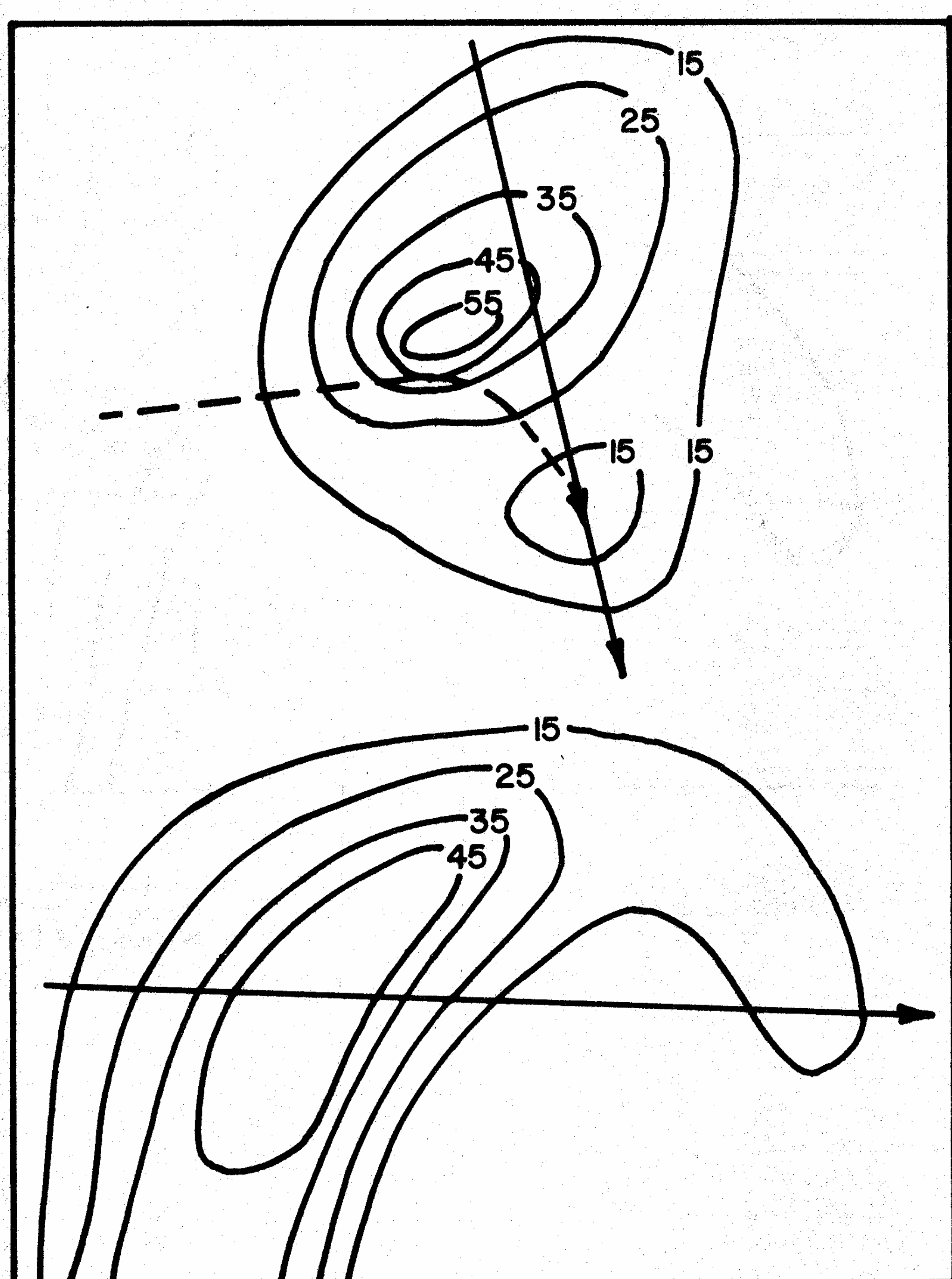

Fig. 3. "Steady-state" penetration pattern. Solid and dashed lines represent two possible patterns depending on conditions occurring at the time of penetrations.

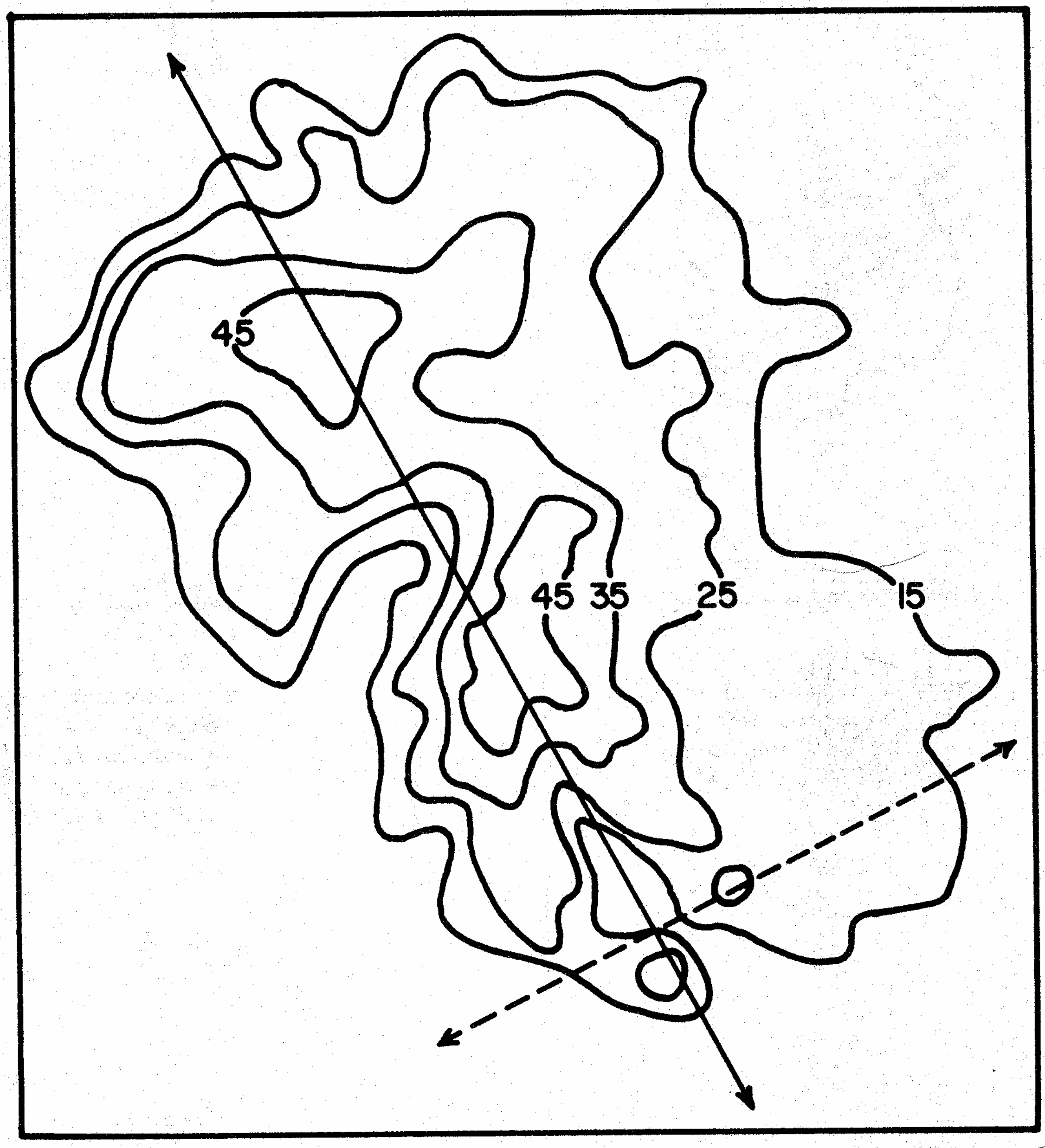

Fig. 4. Schematic showing penetration track of T-28 in multicell storm. Solid track is along line of formation of new cells, while dashed track denotes alternate plan across the line of formation of new cells concentrating on the evolution of a single cell in the system. Isolines are labeled in dBz.

4.3 Calibration Flights

For instrumentation calibration purposes, at least two tower flybys will be performed. The initial plan is to use the Boulder Atmospheric Observatory (BAO) tower if the problems associated with citizen complaints can be solved. If not, the tower at Grover will be used. Airspeeds of 115, 130, and 150 knots IAS will be used. In addition to the tower flyby calibrations, attempts will be made to obtain intercomparison data by flying the research aircraft in formation in clear air and through clouds. These intercomparison flights will be organized by CSD.

5. AIRCRAFT INSTRUMENTATION

The data system on the T-28 includes sensors to measure meteorological and aircraft variables which are recorded on digital magnetic tape. The emphasis in the meteorological measurements is on updraft characteristics and hydrometeor types, sizes, and concentrations. The instruments that will be carried on the T-28 during the 1978 CSD field season and the data to be recorded are summarized in Table 1.

The primary data recording system consists of a Precision Instruments incremental recorder coupled with a multiplexer and digital conversion package by Monitor Labs. The basic recording interval is once per second although, as shown by Table 1, some variables are sampled twice during each one-second cycle. A separate Pertec recorder is used to record data from the PMS probes, as well as for the duplicate recording of certain variables from the primary recording system. Data from the foil impactor and Cannon camera are separate from, but coordinated in time with, the tape recorded data. Audio tapes from the onboard voice/hail mike recorder will also be available.

Air-to-ground UHF telemetry of data from the T-28 will also be available. Three channels will carry voice signals from the cockpit and the aircraft altitude and rate-of-climb, respectively. The receiver will be installed at Grover to provide this information to the project meteorologist in the operations control room. The telemetry transmitter operates at 230.4 MHz.

TABLE 1

List of Variables to be Recorded
and Scientific Equipment to be
Used on the T-28 in 1978

Recorder Data Channel	Variable	Equipment Used
--	Time	Primary data system internal master clock
0	Pressure Altitude (x 5)	Rosemount Model 1301-A-4-B temperature controlled absolute pressure transducer; output amplified by 5 for rate-of-climb calculations
1	Indicated Airspeed	Rosemount Model 1301-D-1-B temperature controlled differential pressure transducer
2	Instantaneous Acceleration	Humphrey Model SA09-D-0101-1 vertically stabilized accelerometer
3	Pressure Altitude	Rosemount Model 1301-A-4-B temperature controlled absolute pressure transducer
4	Pressure Altitude	Ball Model EX-210-B absolute pressure transducer
5	Temperature	Rosemount Model 102AU2AP total temperature probe
6	Temperature	NCAR reverse flow probe
7	Rate-of-climb	Ball Model 101A variometer
8	Manifold Pressure	Giannini Model 45218YE pressure transducer
9	Heading	IAS designed device to enable recording of aircraft heading from gyrocompass
10	VOR Bearing	MetroData Systems, Inc., M-8 used to record from NARCO NAV-122 VOR receiver

TABLE 1 (Continued)

Recorder Data Channel	Variable	Equipment Used
11	DME Distance	MetroData Systems, Inc., M-8 used to record from a Cessna 400 DME unit
12	DME Distance	MetroData Systems, Inc., M-8 used to record from a Narco UDI-4 DME unit
13	Cloud Liquid Water Concentration	Johnson-Williams liquid water concentration probe
14	Blank	
15	True Airspeed	NCAR designed true airspeed computer
16	Angle of Attack	Servomechanisms, Inc., Type TR541 relative wind transducer
17	Aircraft Pitch Angle	Humphrey Model SA09-D-0101-1
18	Aircraft Roll Angle	Humphrey Model SA09-D-0101-1
19	Blank	
20	+5VDC	Reference voltage (optional)
21	Blank	
22	Positive Peak Acceleration*	IAS designed circuit to record peak output from Humphrey Model SA09-D-0101-1 vertically stabilized accelerometer
23	Negative Peak Acceleration*	Same as Channel 22
24	Blank	
25	Pressure Altitude	Same as Channel 0
26	Indicated Airspeed	Same as Channel 1

TABLE 1 (Continued)

Recorder Data Channel	Variable	Equipment Used
27	Instantaneous Acceleration	Same as Channel 2
28-29	Blank	
30	Positive Peak Acceleration*	Same as Channel 22
31	Negative Peak Acceleration*	Same as Channel 23
3 BCD digits	Event Codes (9)	IAS designed digital event codes
3 BCD digits	Frame Count	Frame counter for Cannon particle camera
24 BCD digits	Hydrometeors*	IAS designed hail spectrometer (0.4 - 5.7 cm dia.)
—	Hydrometeors	Williamson Aircraft Company continuous hydrometeor sampler (foil impactor; 0.25 mm - 20 mm dia.)
—	Hydrometeors	Two Particle Measuring Systems optical array spectrometer probes 1) OAP-2D (30-1000 µm dia.) 2) FSSP (3-45 µm dia.)
—	Hydrometeors	Cannon particle camera
—	Voice Recorder	SONY audio tape recorder (2-channel) 1) Pilot's comments 2) Hail impact sounds
—	Visual Cloud	Side-looking super 8-mm movie camera with automatic exposure and remote control

*Denotes new or modified equipment.

6. DATA REDUCTION

Data reduction will operate in two stages: 1) a "quick recall" procedure, whereby reduced data from a particular T-28 mission will be returned to Laramie and Grover in less than 24 hours; and 2) a more thorough reduction following the field season, where the reduced data will be placed in a form more amenable to detailed analysis.

For the quick recall processing, tapes from the primary recording system on the T-28 will be hand carried to Cheyenne and placed on a bus to Rapid City by personnel traveling to Boulder with the PMS data tapes following a penetration mission. After receipt of the tapes in Rapid City by IAS personnel and subsequent reduction on the School of Mines computer, plots of the reduced data will be transmitted to personnel at Laramie and Grover using a Xerox telecopier system. The IAS is providing the telecopiers at Rapid City and Laramie, and CSD has a telecopier for use at Grover. The data plots will be in a form similar to that shown in Figs. 5 and 6. Detailed listings of the recorded data will also be returned to Laramie by bus for comparison with expected instrument performance.

Data reduction following the field season will result in plots of variables or combinations of variables with respect to time for each penetration for days to be selected from the 1978 season. These plots can be used for detailed analysis of data for assigned test cases. The general form will be as shown in Fig. 5, but much more flexibility in presentation and programming is possible.

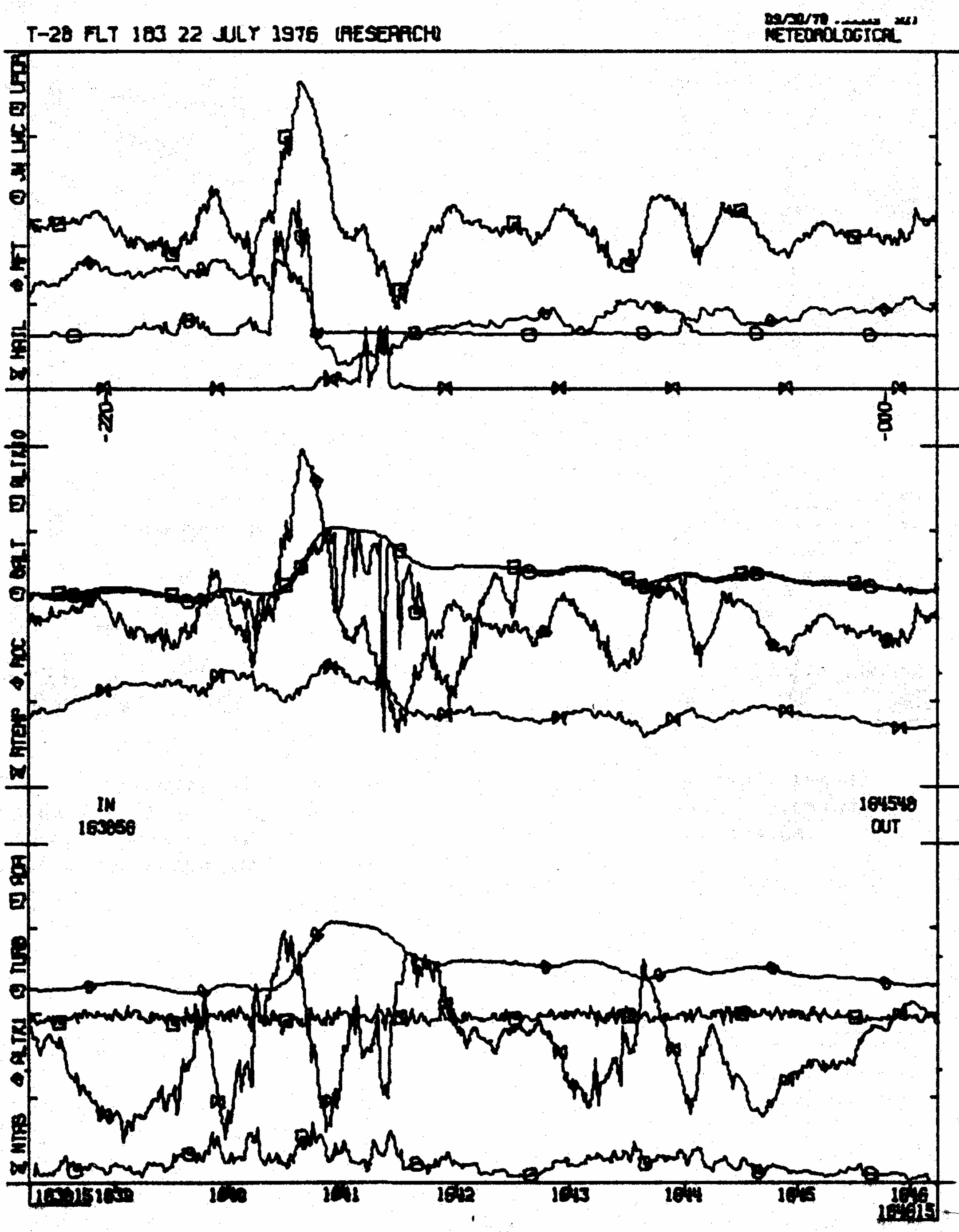

Fig. 5. Example of reduced meteorological data from rapid recall output of Flight 183, 22 July 1976. The topmost trace indicates updraft speed (scale +25 to -25 m/sec), and the other traces depict variables indicated along the left-hand edge.

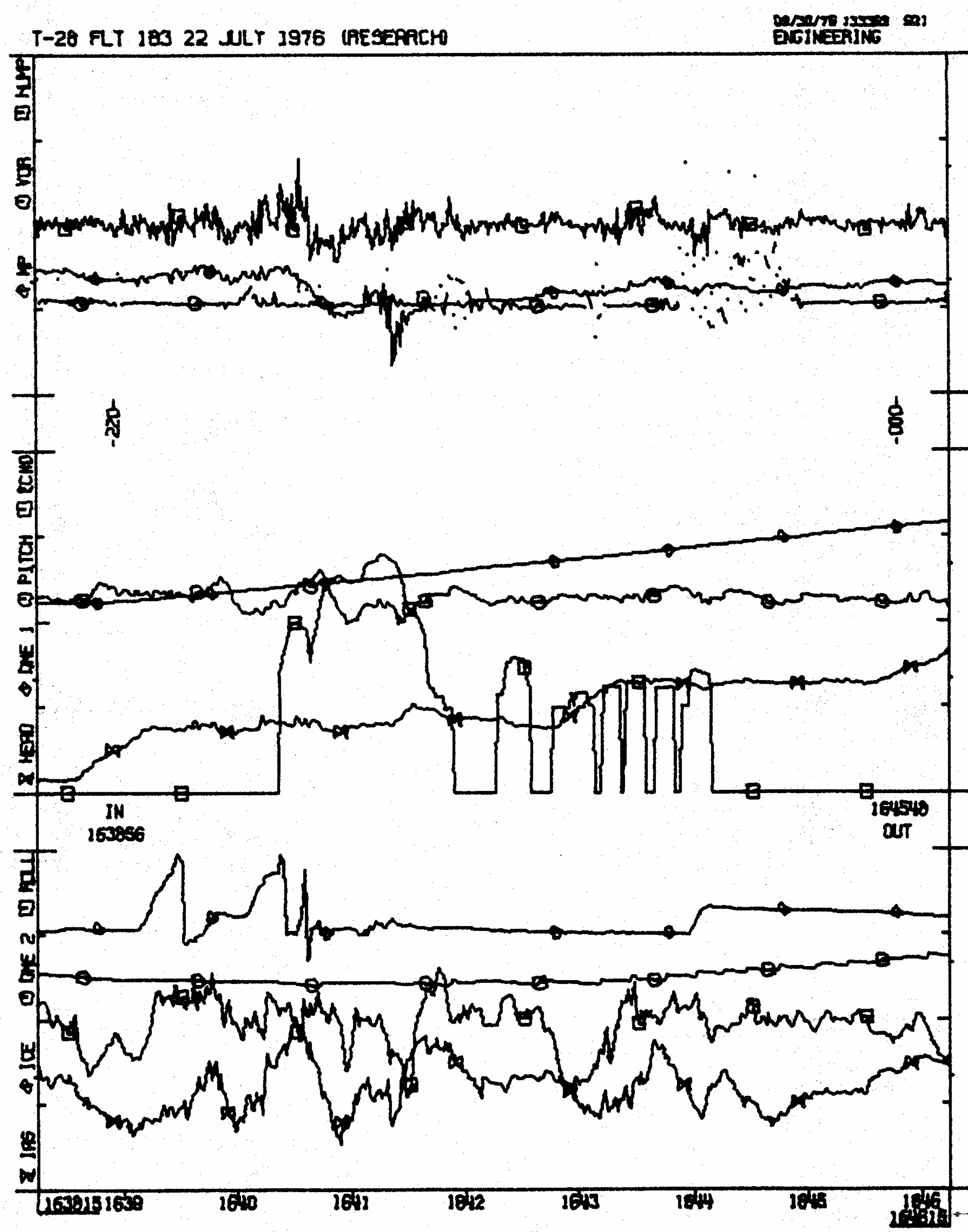

Fig. 6. Example of reduced engineering data from rapid recall output of Flight 183, 22 July 1976. The topmost trace indicates the vertical accelerations of the aircraft, (scale +3 to -1 g) and the others depict variables indicated along the left-hand edge.

7. BRIEFINGS

IAS personnel will particiate in the daily briefings to be held at Grover. The project meteorologist will be available for preparation and presentation of information at these briefings. This includes weather and debriefing type information, as well as information pertaining to the status of the T-28 and its equipment.

IAS personnel also plan to have informal debriefing sessions using the T-28 quick recall data and any other data that are available from the operations, such as radar data, etc. Because of the distances involved, much of the information available will have to be discussed over radio between Grover and Laramie. Many of the same items will be discussed at the briefings mentioned in the previous paragraph. A possible end result will be a nearly complete ranking of the days on which missions occurred by the end of the field season, thus leading to an early data reduction schedule for case study analysis.