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FINAL REPORT OF T-28 ARMORED AIRCRAFT DURING THE PERIOD 1 MAY 1971 - 1 MAY 1972

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Institute of Atmospheric Sciences

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ABSTRACT

A North American T-28 aircraft has been developed as a research tool to investigate the inside of active mature thunderstorms.

The objectives of this project under Prime Contract Number NSF-C460, Subcontract Number NCAR 182-71 were to:

1) Ready the aircraft for use on the National Hail Research Experiment during the 1971 research season.

2) Use the T-28 during the research season to gather data during penetrations of thunderstorms in the National Hail Research Experiment's operating area.

The scientific objectives were to analyze data gathered during these penetrations to determine:

1) The updraft structure in regions of hail formation.

2) The composition of high radar reflectivity zones.

3) The ice-water budgets of hail-producing regions.

The T-28 experienced two complete engine failures in May and June of 1971 precluding its use during the 1971 field season. A Beechcraft Baron was leased to fulfill some contract obligations. It was used as a platform to test some of the T-28 instrumentation and as a cloud seeding vehicle.

The data acquired from the instrumentation package proved to be a valuable test for the instrumentation package and a means of trouble shooting the system.

Future requirements for the T-28 system were identified. Three cases were seeded with the Baron during the 1971 field season.

At the conclusion of the 1971 operational season all efforts were directed back to the T-28.

A feasibility study was conducted to determine the best course of action to build a penetration aircraft for the 1972 and subsequent NHRE research seasons. The course of action dictated by the feasibility study was to give the T-28 a major airframe overhaul and update, and replace the engine with one of proven performance.

The airframe overhaul and new engine installation was accomplished during this contract period. The data package was modified to make it more versatile and additional instruments were added to better define the ice-water budget and the updraft profile.

Radar support requirements were defined for T-28 cloud penetrations.

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1. INTRODUCTION AND BACKGROUND

This report summarizes the work done under Prime Contract Number NSF-C460, Subcontract Number NCAR 182-71 during the period 1 May 1971 to 1 May 1972.

1.1 Development of T-28 Concept and System

The concept of using an aircraft to penetrate thunderstorms in an attempt to gather scientific data has a long history, probably originating in 1949 with the thunderstorm project (Byers, 1949). The idea of developing a special aircraft to penetrate thunderstorms, gather essential data and not be concerned with hail damage began to take shape at the Institute of Atmospheric Sciences in 1966 with the award of an NSF grant to begin work on developing such an aircraft. This work is reported upon by Williamson and MacCready, 1968; Williamson, 1969; and MacCready and Williamson, 1970.

A North American T-28 (N510MH) aircraft (Fig. 1) was acquired and armor plated for hailstorm penetration by a commercial firm under previous grants to the South Dakota School of Mines and Technology from the National Science Foundation. The aircraft was delivered to the South Dakota School of Mines and Technology in January 1970. Two engine failures occurred during this contract period, one on 6 May 1971 and the other on 18 June 1971. These failures totally destroyed the two engines involved precluding use of the T-28 as planned on the National Hail Research Experiment (NHRE) during the 1971 field season.

The reasons for the engine failures were never fully discovered, however, some ideas were put forward. The engines were from the lowest bidder and hence quite possibly lacked the quality desired. The first engine failure seemed to be precipitated by a master rod bearing failure. The second seemed to be a result of a master rod failure.

1.2 1971 Field Project

A Beech Baron (N9677Y) was leased so that part of the T-28 instrumentation package could be installed for evaluation and use on the project. The Baron was also configured with cloud seeding flares so that the NHRE could acquire some cloud seeding experience.

The installation of part of the T-28 instrument package on the Baron gave valuable experience with the package. The data obtained were limited by the fact that only flights below cloud base were undertaken.

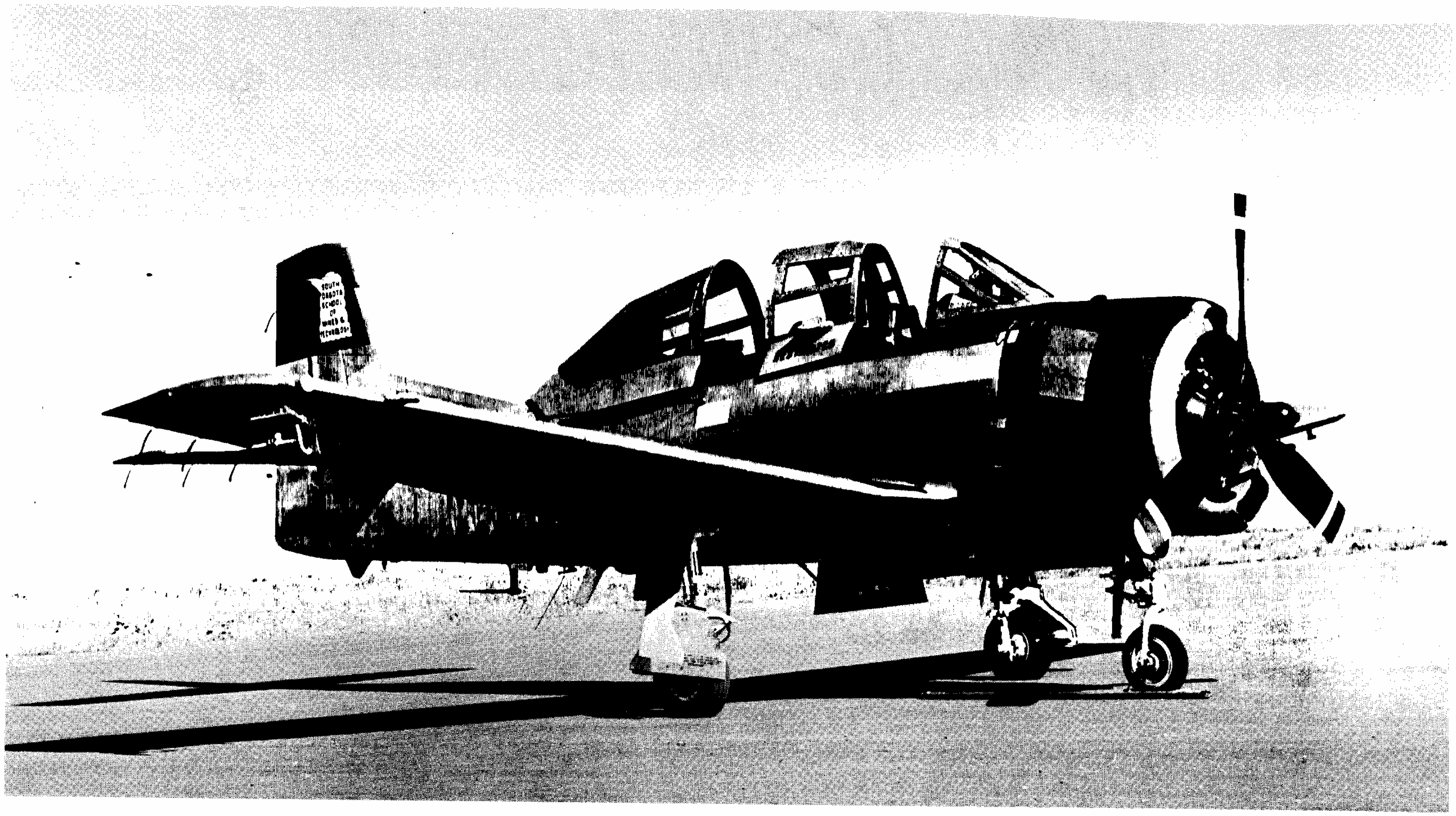

Fig. 1. Armored T-28 used for thunderstorm penetration.

The cloud seeding devices provided a source of experience for NHRE in seeding policies and procedures. Three cases were seeded yielding a good deal of discussion of seeding techniques, procedures, philosophies and equipment. These cases provided valuable background experience for NHRE to develop their 1972 seeding experiment design.

1.3 Objectives of the Project

The ultimate scientific objectives of the project are to determine:

1) The updraft structure in regions of hail formation.

2) The composition of high radar reflectivity zones.

3) The ice-water budgets of hail-producing regions.

1.4 Feasibility Study

At the conclusion of the operation season a feasibility study was initiated to decide on the best course of action to field a penetration aircraft for the 1972 NHRE research season. The decision was to rehabilitate our T-28 with another (newer and better) engine and have the airframe completely overhauled and updated. A summary of the feasibility study outcome is included in Appendix A.

1.5 T-28 Rehabilitation

A number of major modifications were required to make the aircraft a safer, more reliable, and more useful basic aircraft. These changes are given in detail in Section 3. In general they involved updating the aircraft by the Naval Air Rework Facility (NARF) to current U. S. Navy standards. The landing gear, fuel system, compass system, inverters, and torque box were replaced. Numerous structural improvements and updating changes were incorporated. A complete check was made of the entire aircraft and numerous discrepancies corrected.

A zero time since overhaul engine was purchased from a civilian contractor. It is the same basic engine used on all military T-28's. The propeller was furnished by the NARF.

Prior to delivery and after rework the T-28 was inspected and accepted by NARF quality control and NARF test pilots. It met their standards for rework.

The IAS mechanic, Mr. Leonard Block, and the pilot, Mr. Wayne Sand, then completed all the required paper work for Federal Aviation Agency (FAA) acceptance of the aircraft and licensed it in the restricted category with a one time approval Supplemental Type Certificate. This required substantial engineering justification since the T-28 is a one of a kind item in civilian registry. It is the only T-28 in civilian registry with this engine/propeller installation, even though most military aircraft are configured with this engine/propeller.

1.6 Instrumentation

The limited space and power available on the T-28 presented problems in installation of the meteorological instrumentation package. The added problem of using a crew of one necessitates a system which functions as automatically as possible.

The instrumentation package had been assembled and readied for installation prior to the T-28's arrival in Rapid City. There was considerable work remaining, however, to complete the installation and test the equipment prior to use on the NHRE 1972 field project.

New instruments to measure the ice-water content were developed by IAS and NCAR staff for use on the T-28. A Joss hail sensor, total water content device and droplet spectrometer were developed and installed on the T-28. This equipment all involved a good deal of special fabrication to complete installation. The recording capability of the DL620 recorder was expanded from 20 to 29 channels to enable recording these additional parameters.

The rear seat of the T-28 was modified substantially to enable installation of most of the data package. This arrangement allows a technician to ride on test flights to monitor the recorder output and to calibrate some of the sensors.

2. FIELD OPERATIONS DURING 1971

2.1 Beechcraft Baron Acquisition and Mission

Since the T-28 was unavailable for use during the 1971 season, a Beechcraft Baron was leased and made available to the Institute of Atmospheric Sciences, Fig. 2.

The Baron was equipped with portions of the T-28 instrument package so that it could be used as:

1) A test bed for the instrumentation package;

2) A means whereby some vectoring and penetration experience could be acquired; and

3) As a cloud seeding vehicle.

The Baron was equipped and on station at Cheyenne, Wyoming on 9 July 1971.

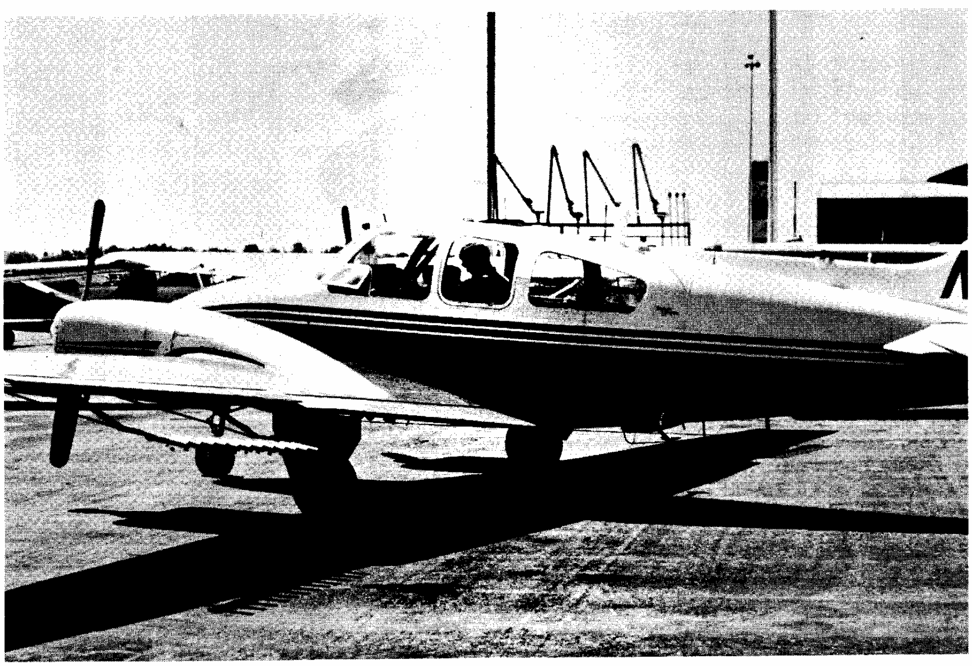

Fig. 2. Beechcraft Baron used during 1971 field season.

2.2 Baron Operations

A summary of flights with flight time and flight purpose is listed in Appendix B.

In summary the Baron:

1) Proved to be a very good means of instrument package check out;

2) Provided no penetration experience because of equipment limitations;

3) Was used successfully as a cloud seeding vehicle.

2.2.1 Instrumentation analysis

The Baron provided an excellent means whereby critical T-28 instrumentation could be evaluated without losing an entire year. Based on experiences with the instrumentation in the Baron an extensive modification program was initiated to modernize and modify the T-28 system to yield better and more meaningful data. See Section 2.3.2.

2.2.2 Operational procedure

Since 1971 was a year designated as a "dress rehearsal" and a year to define problems, the Baron proved to be a means whereby future operational requirements could be better defined. The 1971 season used a procedure whereby the Baron was scrambled by the project meteorologist and controlled by him as to desired activities while airborne. No sophistication was introduced into the aircraft control system above voice link information as to aircraft and storm location. The fact that the project meteorologist was unable to simultaneously determine the aircraft and storm positions from his radar displays was a severe operational limitation for effective use of the aircraft.

All seeding was done in the general area suggested by the meteorologist and when the pilot determined that he was in up-air.

Future requirements determined by the 1971 operational experiences are defined in Section 2.3.1.

2.2.3 Experimental cloud seeding

The experimental design of the cloud seeding portion of the 1971 NHRE project went through a number of revisions. The seeding concept as envisioned by the Institute of Atmospheric Sciences at the beginning of the Baron seeding effort is enclosed as IAS Report 71-15, Appendix C.

These seeding concepts were ultimately reduced to below cloud base seeding in an effort to attain some definitive results from the cloud seeding portion of the experiment during the 1971 field season.

The flares used during the 1971 field season were Olin Corporation (Formulation WM 106) and had a manufacturer's stated efficiency of 10^{12} nuclei per gram of AgI. The flares contained 50 grams of AgI and burned in 20 seconds. During the 1971 field season 71 of these were used to seed clouds. With this limited experience no definite statement can be made on the effects of seeding.

2.3 Results and Conclusions

The data gathered with the portion of the T-28 instrument package installed in the Baron was very limited because of a decision to refrain from cloud penetrations. However, it was of considerable value in:

1) Trouble shooting the system.

2) Defining future operational requirements for the T-28 penetration concept.

2.3.1 Future operational requirements for T-28

Experience with the Baron indicated that for the T-28 to provide meaningful data the following should be available:

1) A ground radar system capable of presenting quantitative reflectivity data displays at various levels in a storm of interest.

2) A ground radar system capable of RHI displays along the penetration path of the T-28.

3) A ground radar system capable of displaying the T-28 track simultaneously with the storm's display.

4) A data display system to display the above information to an individual who in turn could relay vectoring information to the T-28 to enable penetrations of the desired areas.

5) Meteorological data from cloud base and other areas around and inside the cloud should be available for maximum utilization of penetration data.

2.3.2 T-28 instrumentation package redesign

The operational experience with the Baron was the basis for planning future T-28 instrumentation requirements. The objectives of the project further define these requirements.

It was realized that new methods of measuring the updraft structures in the region of hail formation and determining the ice-water budget in this area had to be devised.

The requirement to have access to certain parts of the instrumentation package in flight for calibration purposes was discovered as a result of using the T-28 gear in the Baron.

3. T-28 AND INSTRUMENTATION PACKAGE

3.1 Rehabilitation of the T-28

A feasibility study into the various options available for putting the T-28 back into operation or replacing it was conducted during August of 1971, the results of which are contained in Appendix A. As a result of this feasibility study a number of decisions were made as to the future of the T-28 penetration aircraft. It was decided to overhaul our aircraft completely since it was one of the better basic airframes in the United States and already had the armor plating to withstand flights through hail. It was also decided that we should purchase a better engine for the aircraft. A modification of the airframe was then required to accept this bigger and better engine. It was decided to have the entire job done as professionally as possible. Hence, it was sent to the Naval Air Rework Facility (NARF) at Pensacola, Florida. This is the only place in the United States having a proven capability to do such work on T-28 aircraft.

The T-28 left Rapid City for the NARF, Pensacola on 10 December 1971. The airframe was completely disassembled and loaded on the NCAR FOF truck for shipment. It arrived in Pensacola on 16 December 1971.

Effective 1 December 1971 a full-time mechanic was added to the IAS staff. This man has the responsibility of maintaining and modifying the T-28 throughout the year. He is a licensed airframe and power plant mechanic with an inspector authorization designation.

A hangar-shop facility has been leased at the Rapid City Regional Airport for this purpose. The addition of a heating capability will be required prior to the 1972-73 winter season to enable winter work in this space.

3.1.1 Airframe

While at Pensacola the airframe underwent a complete Navy overhaul which is designated by the Navy as a PN163A. The PN163A was modified slightly to meet the requirements of our specific aircraft. The airframe was updated to current military standards for T-28's. This included:

1) Replacing the nose gear torque box and addition of the new nose landing gear. Figure 3.

2) The fuselage structure was strengthened considerably to accommodate the larger engine. Heavy stress plates were installed on the outside of the fuselage aft of the firewall.

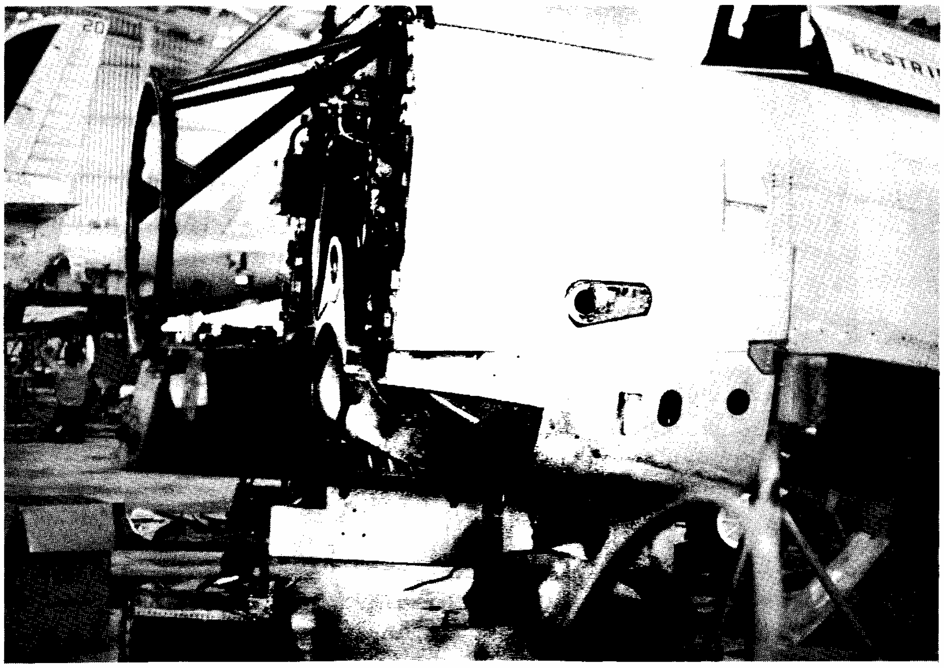

Fig. 3. Torque box replacement.

3) A new fuel system (T-28B compatible) was installed which is a substantial improvement over the system which formerly was in the T-28. The entire wing required major disassembly for this change. Figure 4.

4) A larger oil cooler system was installed with considerable airframe modifications being required to accommodate the larger cooler. Figure 5.

5) The oxygen system was modified and completely overhauled.

6) The old flux gate compass system was removed and a more reliable G-2 compass system installed.

7) New wiring for the sensor probes was installed.

8) A high visibility paint scheme was put on the aircraft to enhance in-flight detection by other aircraft.

9) The forward instrument panel was completely rewired.

10) New 250 VA inverters were installed in place of the original 100 VA inverters.

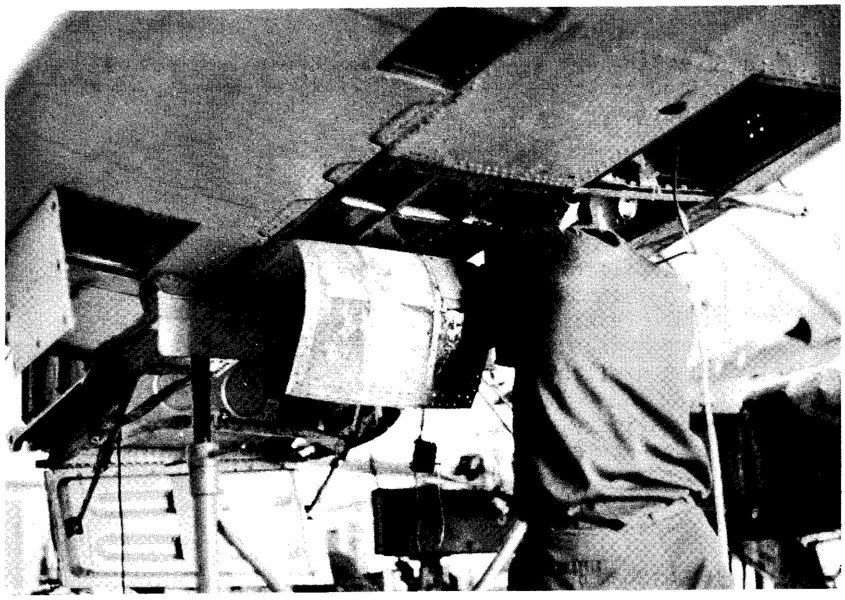

Fig. 4. T-28 wing dismantled for modification and fuel system installation.

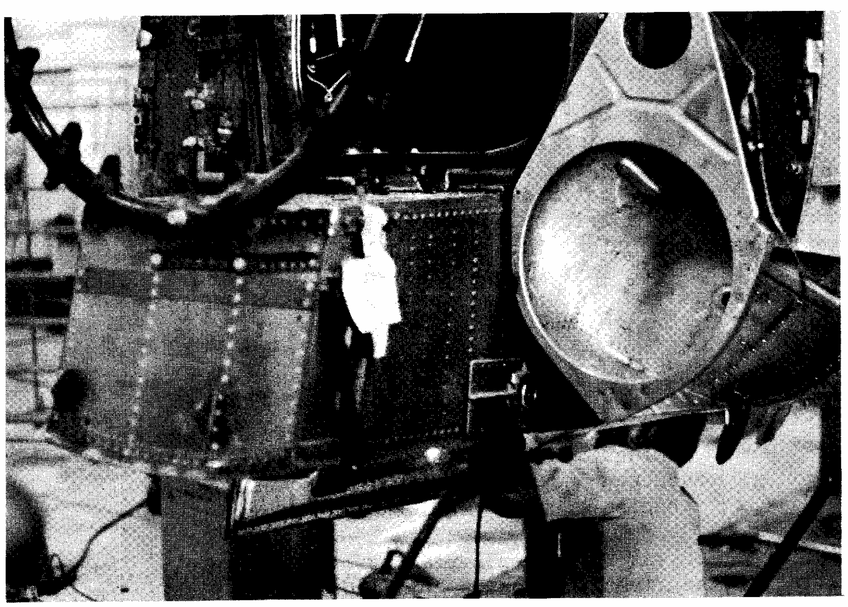

Fig. 5. Oil cooler modification.

Basically the entire airplane was checked and reworked as necessary. It was modified to give us a T-28 which is very nearly a T-28B compatible aircraft.

3.1.2 T-28 engine

A zero time since overhaul Quick Engine Change (QEC) R-1820-86A engine (Figs. 6 and 7) was purchased from Steward-Davis Incorporated of Long Beach, California. This engine was purchased on recommendations from other firms and other individuals as to the quality work available from Steward-Davis. Also, Steward-Davis was the only civilian source which had an R-1820-86A engine available. A military engine was not available.

We took delivery of the QEC unit on 18 February 1972 and delivered it to NARF, Pensacola on 23 February 1972. The NARF, Pensacola modified the QEC slightly to make it T-28B compatible and furnished the propeller so that the entire unit could be installed on our aircraft during final assembly at Pensacola.

3.1.3 T-28 delivery

Mr. Wayne Sand and Mr. Leonard Block went to Pensacola, Florida on 31 March 1972 to be there for the final stages of assembly and acceptance of the T-28. The NARF had accepted most of the mechanical work prior to IAS crew arrival in Pensacola so FAA acceptance checks could begin. Numerous minor items were noted that were NARF acceptable but not FAA acceptable. These discrepancies were all corrected.

A great deal of formal paper work was required to gain FAA acceptance and certification of the T-28 after a military overhaul. In order to achieve the FAA engineering acceptance of this work a trip to their office in Atlanta, Georgia was required. This trip was followed by a trip by one of their representatives to Pensacola for actual inspection of the T-28 prior to approval of a one time Supplemental Type Certificate. Seventeen FAA Form 337's were required prior to FAA engineering acceptance and licensing in the restricted category.

The engine was ground run on 8 April 1972 and some discrepancies noted. One of these discrepancies required removal of the nose section of the engine to install an O-ring omitted during engine overhaul. Nine days were required to isolate this problem and correct some of the other discrepancies. Another week was required to correct all other discrepancies found by various inspectors.

The T-28 was finally accepted by everyone involved and test flown for the first time on 26 April 1972. All flight discrepancies were corrected and Mr. Wayne Sand flew the T-28 to Rapid City on 1 and 2 May 1972.

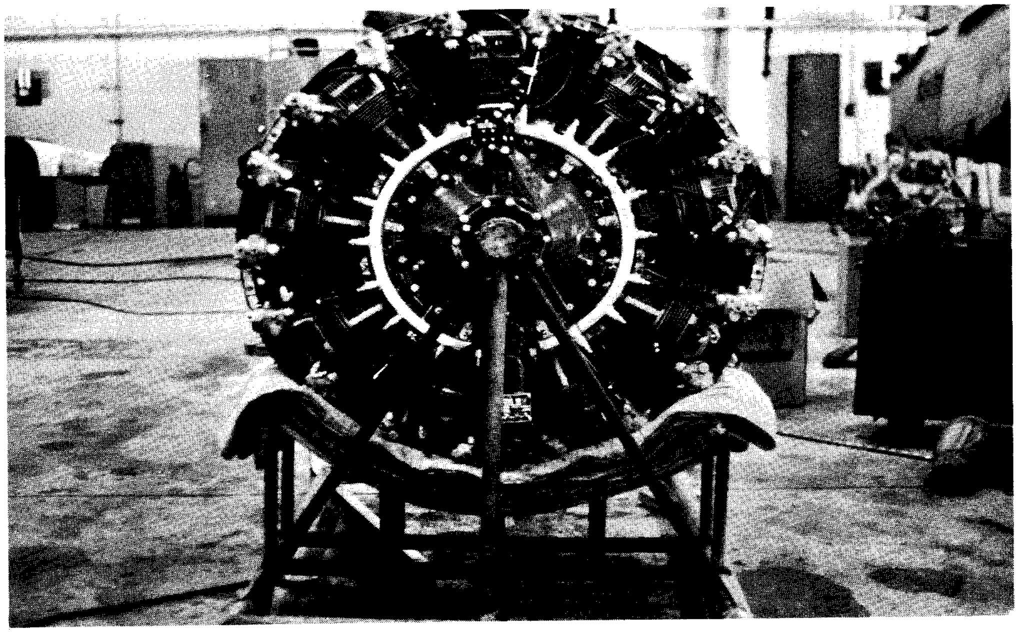

Fig. 6. R-1820-86A QEC.

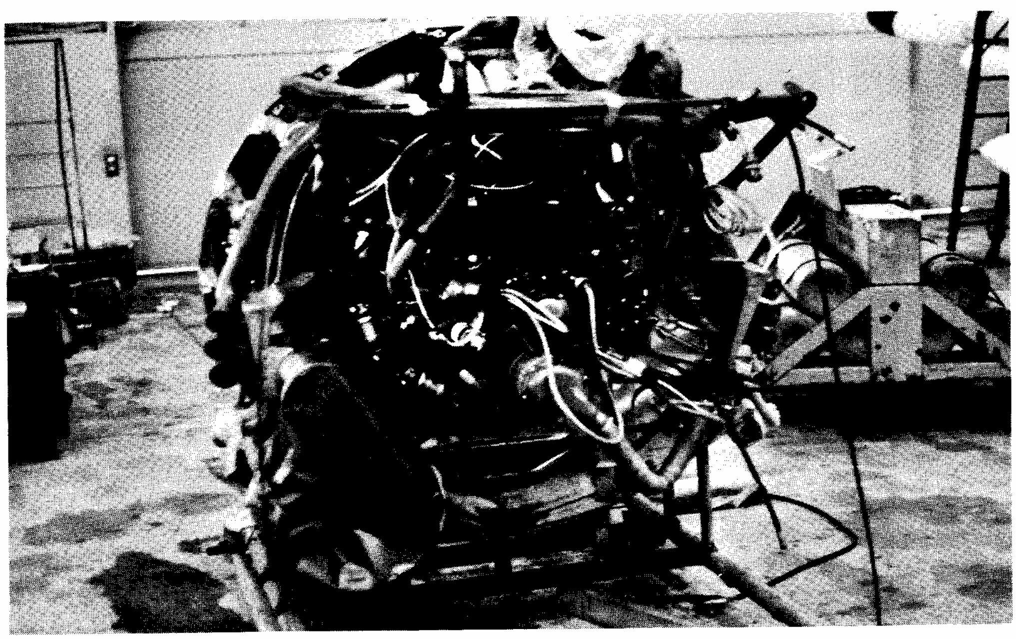

Fig. 7. R-1820-86A QEC.

3.2 Instrumentation

A complete list of the instruments (with performance specifications) to be used during the 1972 field season is included as Table 1. Instrumentation previously used is discussed in Sand et al., 1972. Substantial modification of the package was performed during this contract period along with the addition of various sensors.

3.2.1 Relocation of instrumentation package in aircraft

Due to limited space in the T-28, the location of the instrumentation package and various sensors is a very critical item. During previous seasons the entire instrumentation recording package was located in the aft fuselage area of the aircraft. This made it impossible to take readings from the tape recorder and make adjustments while the aircraft was in flight. To overcome this difficulty, the DL620 and various components of the instrumentation system have been relocated in the rear seat of the T-28 for easy access during calibration flights. To accomplish this change, the rear cockpit of the T-28 had to undergo considerable modification to accommodate the instrumentation package. The rear instrument panel (Fig. 8) and the rear pedestal (Fig. 9) are examples.

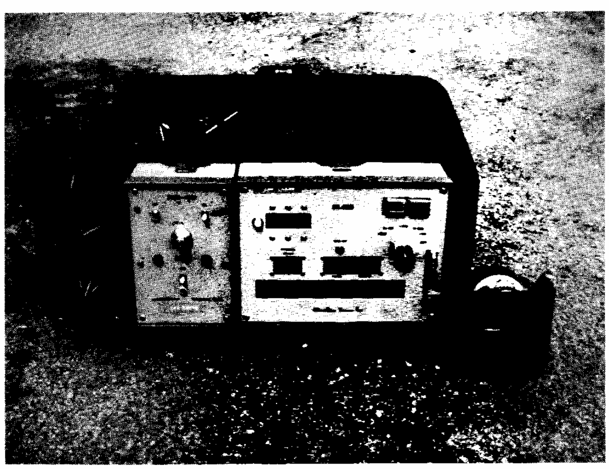

Fig. 8. T-28 rear seat instrumental panel, modified.

TABLE 1. T-28 Instrumentation Summary and Specifications

Aircraft N510MH - Aircraft Instrumentation

Parameter Measured	Instrument Type	Manufacturer and Model No.	Combined Performance of Transducer, Signal Conditioning and Recording: Range	Accuracy	Time Constant	Precision	Resolution
A. Temperature	Thermistor TS 22	MetroData TVH 26	-30° to +30°C	± 0.5	0.605 sec	.03°C	.03°C
B. Temperature	Platinum Resistance	Rosemont 102AU2AP	-30° to +30°C	± 0.4°C	0.605 sec	.03°C	.03°C
C. Liquid Water Content	Laser	NCAR (Kyle)*	1μ to 4 mm 30 size classes				
D. Liquid Water Content	Hot wire	Johnson-Williams LWH	0 to 5 gm/m³	± 20%	0.605 sec	.005 gm/m³	.005 gm/m³
E. Indicated Airspeed	Airspeed Transducer CIC 7100	MetroData TVH 26	70 to 350 Kt	± 3 Kt	0.605 sec	0.35 Kt	0.35 Kt
F. Rate of Climb	Variometer	Ball 101A	-6000 to +6000 f/m	± 2%	0.605 sec	6 f/m	6 f/m
G. Position Azimuth	VOR Signal Conditioning	MetroData VT 21	0 to 360°	± 2°	0.605 sec	0.36°	0.36°
H. Position Slant Range	DME Signal Conditioning	MetroData DME Amplifier	0 to 100 mm	± 3%	8 sec max	0.5 mi	0.5 mi
I. Pressure Altitude	Pressure Transducer	Ball EX-210-B	-200 to 30,000 ft	± 1%	0.605 sec	30 ft	30 ft
J. Pressure Altitude	Pressure Transducer CIC 7000	MetroData TVH 26	0 to 30,000 ft	± 195 ft	0.605 sec	30 ft	30 ft
K. Raindrop Spectrum	Impact Transducer	MetroData RR40	0.35 to 7.35 mm 9 size classes	± 1 size class	0.605 sec	1 size class	1 size class
L. Vertical Acceleration	Strain-gauge Bridge	Statham Instr. Inc. A45-15-350	-15 g to +15 g	± .1575 g	0.605 sec	.0075 g	.0075 g
			-----Planned to be changed for 1972 Project Season-----				
M. Hail Sensors	-----Several under development for 1972 Project Season-----						
N. Time	Crystal Controlled Oscillator	MetroData DL620	0 to 24 hrs in seconds	± 2 sec/24 hr	0.605 sec	1 second	1 second
O. Sound of hail Impact on Windshield	Microphone & Tape recorder	Aiwa TP-1004†	N/A	N/A	± 5 sec	N/A	N/A
P. Manifold Pressure	-----Planned to be added for 1972 Project Season-----						
Q. Event Condition	Voltage Level	Lab Fabricated	0 to 9 events	± 5 mv	0.605 sec	N/A	N/A
R. Liquid Water Content	Evaporator	NCAR (Kyle)	N/A	N/A	N/A	N/A	N/A

Description of Recording System: MetroData DL620, 29 channel, digital recorder. Speed of 48 CH/sec uses 60 min cassettes. A, B, D, E, F, G, H, I, J, K, L, N, P, and Q recorded.

*Recorder to be provided by NCAR.

†Aiwa TP-1004 audio magnetic tape recorder. Speed of 1 7/8 in/sec. Two channels (stero-observer voice, hail impact) uses C-120 cassettes. 60 min/side.

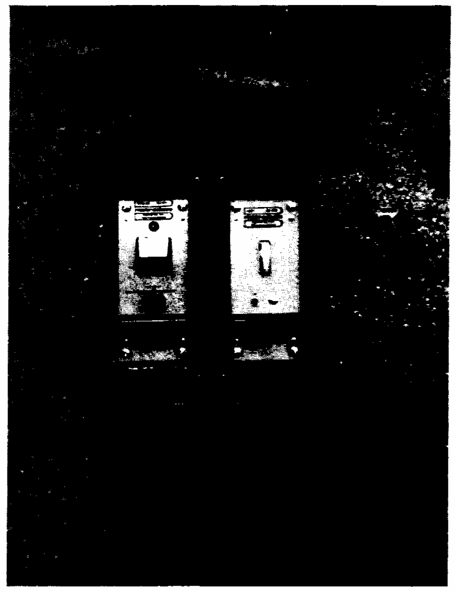

Fig. 9. T-28 rear seat instrument pedestal.

3.2.2 Hail sensors

To study the ice-water budget in a region of hail formation, a reliable system for measuring quantity and size of hail is required. A number of ideas are currently under development for accomplishing this objective. At least two separate systems will be available and operational during the 1972 field season.

The Joss hail sensor will be included in the T-28 data system. The Joss sensor was purchased by IAS from Dr. Joss who designed and tested the instrument. The Joss sensor works as a momentum sensor with hydraulic damping. Figure 10 shows the Joss sensor mounted on the T-28.

A windshield noise sensor was conceived at IAS to acquire a qualitative measure of the presence of hail. The noise of hail striking the windshield is recorded on the second channel of the voice recorder.

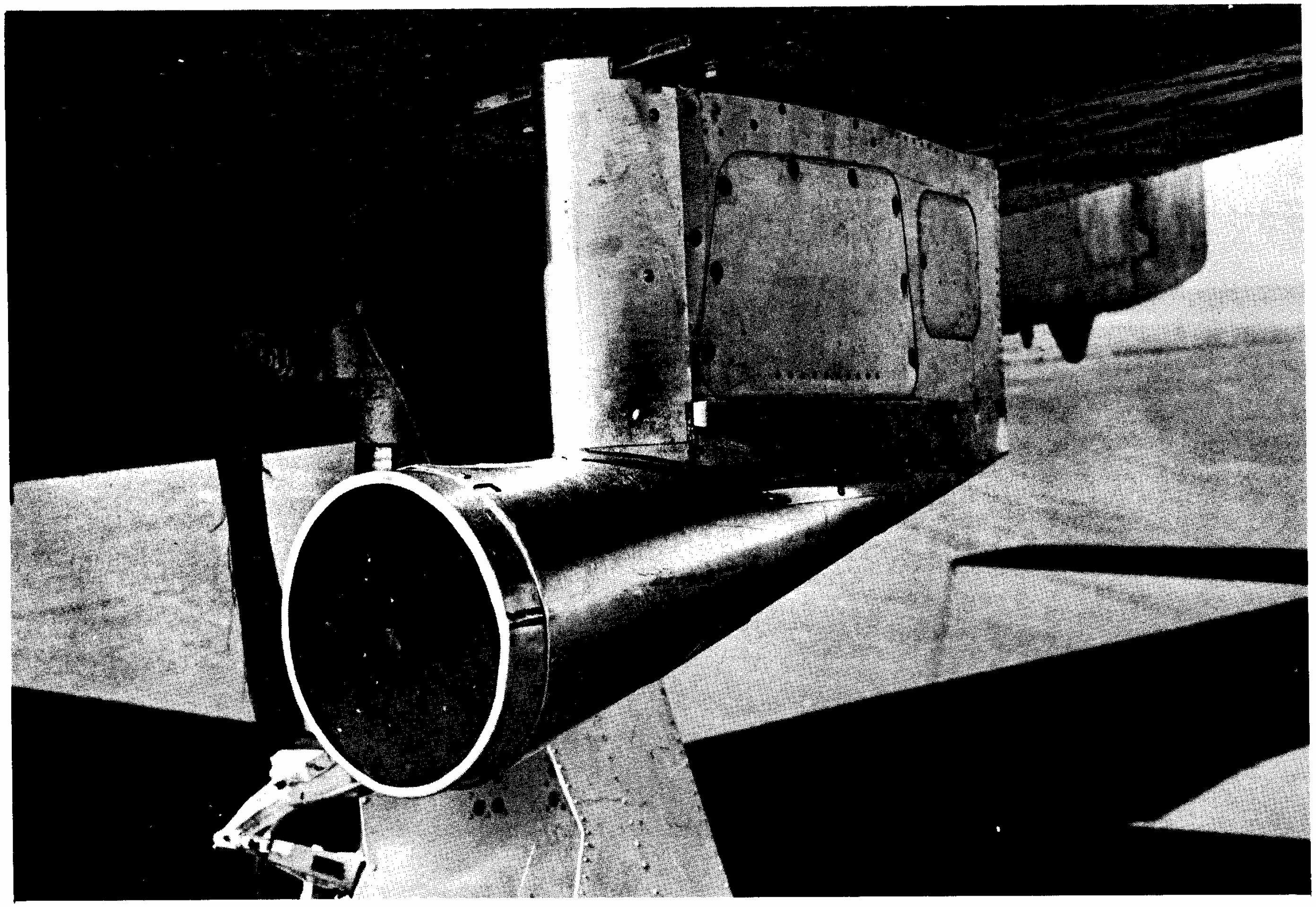

Fig. 10. Joss hail sensor installed below T-28 left wing.

3.2.3 Vertical velocity measurements

To study the vertical velocity profile during penetrations with the T-28 it is necessary to record the updrafts as accurately as possible. To attain this goal, the Ball variometer was sent to the manufacturer (Ball Brothers of Boulder, Colorado) for calibration. The Ball variometer has a range of ± 6000 feet per minute and should be relatively accurate within this range after the calibration procedures. To enable even more accuracy to be ascribed to the vertical velocity measurements made with the T-28, manifold pressure and airspeed will be recorded. The recorded rate-of-climb will then be corrected using these two parameters.

3.2.4 Kyle spectrometer

One instrument to be carried on the T-28 is a condensed water content meter, developed by Dr. Kyle at NHRE. Figure 11 is a photograph of the section of the instrument which mounts outside the aircraft.

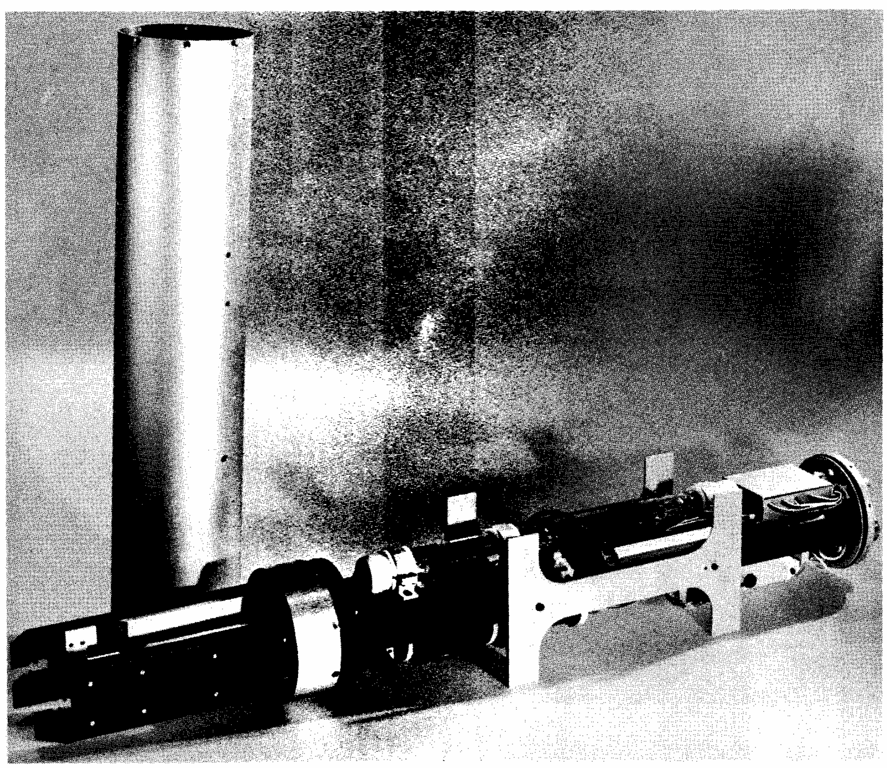

Fig. 11. Kyle spectrometer parts for T-28 right wing tip.

The condensed water meter is a three-stage instrument which measures the number and size of drops by the extinction of light as the drop passes through the beam of a He-Ne laser. The three stages will size droplets from 10 to 80 microns diameter; 80 to 640 microns, and drops larger than 640 microns. Within each of these stages the drop diameters are broken into ten subclasses. The collection area for the largest range is 10 cm^2, for the intermediate size range is 0.2 cm^2, and is a function of droplet size for the smallest size range. The three beams are derived from a single continuous output laser by the use of beam splitters.

3.2.5 Kyle total liquid water device

An evaporative instrument developed by Dr. Kyle will also be carried on the T-28. This instrument will measure the condensed water in a cloud by evaluating the quantity of energy required to evaporate the water. It will give no information about the size distribution of the drops, but it is a very rugged and simple instrument which can reliably operate in the severe environment of the cloud. See Fig. 12.

3.2.6 DL620A recorder channel expansion

Due to the addition of these various instruments in the T-28 instrumentation package a requirement existed for more data channels. The DL620A system was expanded to enable recording of time plus 18 digital channels and 9 analog channels. This should enable recording all of the desired parameters during the 1972 field season and should permit some further expansion.

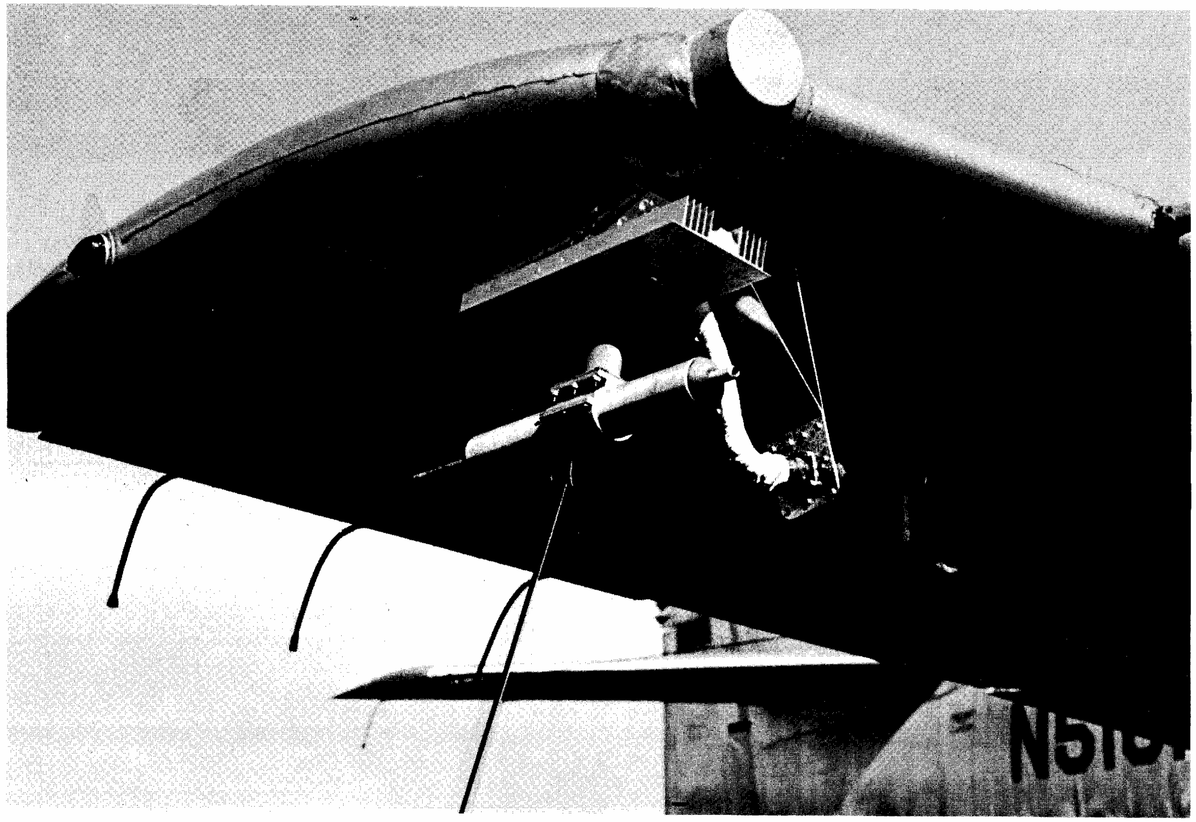

Fig. 12. Kyle total liquid water device installed below T-28 right wing tip.

4. DATA REDUCTION AND ANALYSIS

4.1 Previous System

Development of the basic data reduction and analysis was accomplished under a previous grant and is described in Sand et al., 1972. Basically the DL622 tape cartridge reader output was played into a PDP-8 computer where the data was transferred to DECtape reduced to engineering units, and printed out or displayed in analog form on a cathode ray tube for analysis.

4.2 1972 Requirements

Since the 1972 field season is to be the first year of NHRE where the full research effort will be in the field many additional requirements were established.

The data had to be on seven-track industry-compatible magnetic tape in engineering units so other institutions would have access to this data. A requirement for quick turnaround of the data was also established.

The T-28 data package was expanded to enable recording additional parameters. Manifold pressure and airspeed were added variables to be combined with rate-of-climb information to better define the cloud updrafts.

A Joss hail sensor was added so hail encountered could be more quantitatively recorded. A total water device was added. All this additional equipment required additional channels in the recording system so it was necessary to expand the recording capability of the DL620A from 20 to 29 channels. For a complete list of the channel assignments see Table 2.

4.3 System Developed for 1972 Data Reduction

The DL620A ¼ inch magnetic tape cartridge containing data from 29 input channels will be played into the PDP-8 through the DL622 reader. The PDP-8 requires some re-programming to accept the additional channels of data. The PDP-8 will transfer the raw data to DEC tape for permanent storage and seven-track magnetic tape for analysis on other computers. A seven-track recorder was acquired in 1972 to permit production of industry compatible tapes.

The seven-track tape will then be played into the CDC 3400 computer at the South Dakota School of Mines and Technology's computer facility for reduction to engineering units. A new program will be required to reduce the data on the CDC 3400.

TABLE 2: T-28 Instrumentation Data Recorder Channel Assignments

Channel	Data
1	Time - hours, minutes, and seconds
2	Time - hours, minutes, and seconds
3	Ball altimeter as pressure in inches mercury
4	Indicated airspeed in knots
5	VOR position given as radial from station
6	WSI altimeter in feet MSL
7	DME recorded as nautical miles
8	Manifold pressure in inches mercury
9	Rosemont temperature in degrees centigrade
10	WSI temp in degrees centigrade
11	Johnson-Williams liquid water content gm/m^3
12	Ball variometer, rate-of-climb in ft/min
13	Regulated 5-volts reference voltage
14	Accelerometer in G's
15	Kyle total water content
16	Kyle total water content
17	Vacant
18	Voice event
19	Event codes
20	Vacant
21	Joss hail sensor as number of stones in each of 8 classes
22	Joss hail sensor as number of stones in each of 8 classes
23	Joss hail sensor as number of stones in each of 8 classes
24	Joss hail sensor as number of stones in each of 8 classes
25	WSI RR40 as number of raindrops in each of 10 classes
26	WSI RR40 as number of raindrops in each of 10 classes
27	WSI RR40 as number of raindrops in each of 10 classes
28	WSI RR40 as number of raindrops in each of 10 classes
29	Vacant

The reduction scheme provides for the data to be printed out in engineering units or to be transferred to seven-track magnetic tape, or both.

The 1972 data handling flow chart is represented in Fig. 13.

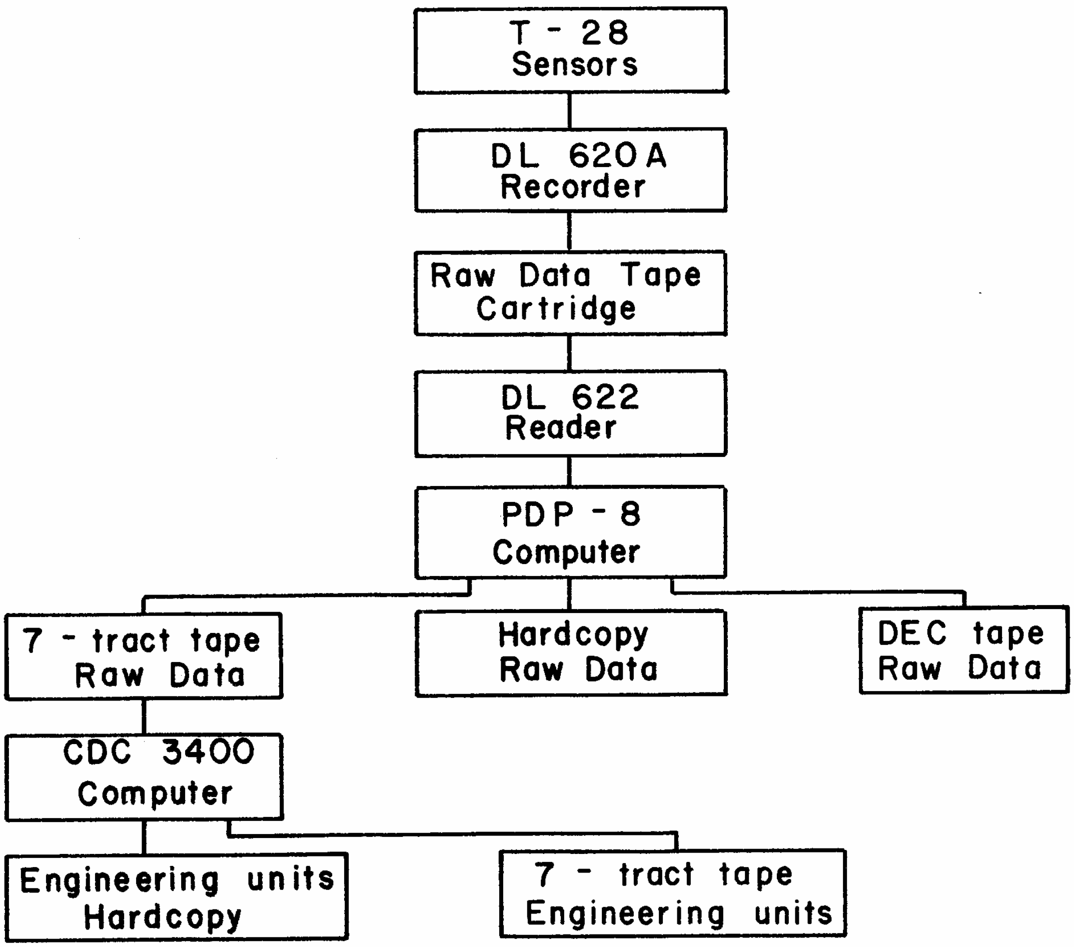

Fig. 13. T-28 data reduction flow chart.

5. OUTLOOK FOR 1972 FIELD SEASON AND BEYOND

5.1 Instrumentation

The 1972 field season instrumentation is discussed in Section 3. The primary improvements to the system used in previous years are the inclusion of additional hail sensors and the inclusion of instrumentation to give more resolution to the vertical velocity measurements. The DL620A recording capability has been expanded for the 1972 field season. Most of the instrumentation package has been relocated in the rear cockpit of the T-28 to enable in-flight calibration of the system and in-flight trouble shooting.

Hail sensors development will continue in future years to upgrade the capability for measuring quantity and size of hailstones.

In future years added emphasis will be placed on cloud physics studies. It is planned to include devices such as the foil impactor and formvar replicator to give detailed cloud physics data and aid in the search for cloud seeding effects.

Continued emphasis will be placed on vertical velocity measurement resolution in future years.

The limited number of extra DL620A channels are available for future recording requirements.

5.2 T-28 Penetration Aircraft

A mechanic has been added to the IAS staff primarily for the purpose of T-28 maintenance. A hangar/shop facility was established during 1972 and will be improved in future years to better enable the Institute mechanic to maintain the T-28 and related equipment.

Continued emphasis will be placed on the ability of the aircraft to withstand hail and turbulence during penetrations. Undoubtedly, continued research and development will be required in this area to update and strengthen the aircraft for continued penetrations of mature thunderstorms.

5.3 Radar and Other Support

High quality radar support is an essential part of the T-28 mission. For the T-28 data to be as meaningful as possible, it is required that radar data be recorded and made readily available for correlation with the data gathered during T-28 penetrations. The system must contain a capability to accurately correlate the T-28 data in space with radar data.

Airborne observations external to the cloud and ground observations will demand continued emphasis in future years to make the T-28 data as meaningful as possible.

6. SUMMARY AND CONCLUSIONS

Two total engine failures were experienced on the T-28 prior to the 1971 field season. IAS staff then assembled strategic parts of the T-28 data system in a Beechcraft Baron to participate in the research effort during 1971 and provide answers to some critical operational questions.

The Baron proved to be a means of evaluating certain important parts of the T-28 instrument package. Many T-28 instrument changes were considered necessary as a result of the experience with the Baron.

Ground radar requirements were defined in more detail as a result of the Baron experiences.

The NHRE cloud seeding effort was initiated with the Baron. A great deal of discussion about cloud seeding methods was generated and the cloud seeding scheme to be used in 1972 evolved.

A feasibility study into the various options of putting the T-28 back into operation or replacing it with an equivalent aircraft was completed in September of 1971. It was decided to replace the engine on the T-28 with one of a higher quality and proven performance. It was decided to give the airframe a major overhaul and update. All this work was accomplished by sending the T-28 through the Naval Air Rework Facility at Pensacola, Florida for an airframe overhaul and update. An engine was purchased from Steward-Davis of Long Beach, California. The T-28 arrived back in Rapid City on 2 May 1972.

The instrumentation package in the T-28 was redesigned to better accommodate the requirements of the project. Most of the system was moved to the rear seat where it is accessible to a technician during a test flight.

It is felt that during this contract period a T-28 research platform was developed and improved to the point that it is now safe and reliable. Continued improvements will be required to constantly improve the aircraft and data system.

ACKNOWLEDGMENT

The work described in this report was part of the National Hail Research Experiment and was supported by the National Science Foundation, Prime Contract Number NSF-C460 (Subcontract Number NCAR 182-71).

Arrangements to rehabilitate the T-28 were made between the National Science Foundation and the United States Navy. The actual work was accomplished by the Naval Air Rework Facility at Pensacola, Florida.

Appreciation is expressed to Mr. Leonard Block for maintenance of the aircraft, and to Mr. Kenneth "Chuck" Jasper for his outstanding work on the instrumentation system.

Mrs. Helen Smith compiled the list of personnel in Appendix D. Mrs. Karen Brown and Mrs. Joie Robinson typed the manuscript.

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APPENDIX A: Results of Feasibility Study

30 September 1971

AIR MAIL

Dr. William C. Swinbank, Director
National Hail Research Experiment
National Center for Atmospheric Research
P. O. Box 1470
Boulder, Colorado 80302

Dear Dr. Swinbank:

This letter is to serve as a summary of the results of our feasibility study into the various options available for putting our T-28 back into operation or replacing it with an equivalent aircraft.

The past trend of engine problems on the T-28 dictates the need for a change in our source of engines and possibly the need to use another type engine. The airframe of the T-28 has various shortcomings that need extensive attention. These problems suggested the possibility of replacing the aircraft completely.

We arranged for a consultant from the Navy's NARF (Naval Air Rework Facility) Pensacola to come to Rapid City to inspect our aircraft and to determine its general mechanical condition. His conclusion was that our basic airframe was very sound and worth repairing. The general overall condition of the airframe is better than that of most of the Navy's T-28 aircraft. The shortcomings in our aircraft were due to its lack of airframe updates and structural strengthening modifications since it was released from the military inventory in 1962. The most current recorded military modification was in 1957. This, combined with some unsatisfactory airframe changes since 1962 pointed out the need for a major airframe rework.

The options as they were explored by Wayne Sand and Bill Myers suggested a best course of action. The desire for a reliable and safe penetration aircraft was a paramount consideration. The most promising alternative to get a good aircraft into the air by the 1972 NHRE summer season was an important consideration. There were a number of options considered, each of which will be discussed briefly. Our conclusion and the merits of this conclusion are covered.

The options were:

1. Replace the T-28 with a T-28B from the military or surplus inventory.

   a. Advantages.

      An aircraft from this source would have all the current updates and modifications developed over the last few years. It would be a good functioning aircraft if we could acquire one from the military inventory.

   b. Disadvantages.

      We cannot get one. There are no excess aircraft in the military inventory. Their aircraft are in worse basic condition than our T-28 as far as corrosion and high flight time are concerned.

      The problem of re-armoring such an aircraft is substantial.

2. Purchase another T-28 on the civilian market and modify it to fit our needs.

   a. Advantages.

      The aircraft would be in good flyable condition.

   b. Disadvantages.

      No good aircraft are available. These aircraft would quite possibly be just as far out of date as our T-28 in the area of recent military engineering changes. This aircraft would need to be armored.

3. Switch aircraft completely to an A-1E.

   a. Advantages.

      This was the aircraft chosen during the initial study to develop a thunderstorm penetration aircraft, but was not available at that time. It is still felt that this aircraft would be an outstanding choice. It is very powerful and capable of carrying a tremendous load. It would have no problem operating at the altitude of interest.

b. Disadvantages.

It is a larger aircraft with a much larger engine than the T-28 and hence more expensive to operate. The cost of engineering the armor plate and armoring the aircraft is high ($50,000). The engine is very large and complicated, a turbo compound R-3350-26WA. An overhaul would be extremely costly ($20,000 for labor alone). We do not know that we would be able to get a good aircraft on the surplus market and feel that we would be getting into an area of too many unknowns to have a high probability of getting into the air by the 1972 season.

4. Repairing our T-28 at Rapid City with another R-1820-87 engine.

   a. Advantages.

   This is the easiest way out.

   b. Disadvantages.

   We would still have all the airframe problems which now exist on the aircraft. The R-1820-87 engine is very old (1941 vintage) and there are much better and more powerful and reliable engines available which weigh about the same.

5. Send our T-28 to a commercial contractor to have the engine replaced and repair the airframe.

   a. Advantages.

   This is a fairly rapid response-time method of getting our T-28 back into the air. We should be able to get good service from either of the two major companies contacted.

   b. Disadvantages.

   There are few T-28's flying under civilian registry, hence no company has working experience on the basic airframe. The recent engineering to improve the airframe has all been done by NARF Pensacola and is unavailable to private enterprise. We would very possibly not get the quality job that we would like.

   Engines on the civilian market are not as strong internally as those used by the military.

6. Send our T-28 to NARF, Pensacola to have the airframe and engine work accomplished.

   a. Advantages.

   They have all the necessary experience and engineering to do the job and a record of doing a good job on the Navy's T-28's. NARF can provide an R-1820-86A engine equal to that used on military aircraft. This engine gives them minimal trouble when used on a flight instruction aircraft. We would get an up-to-date aircraft which we could count on from this source.

   b. Disadvantages.

   Our T-28 would have to be torn down and transported to Pensacola for this work. There would quite possibly be some delays at a facility such as NARF but they quote a 90 day in-shop time. The cost of this option is high.

Conclusions.

We feel that it would be best to do the job right and get a good, reliable aircraft. This means we think our T-28 should go to NARF, Pensacola to have the engine replaced with an R-1820-86A and have the airframe reworked to meet current military T-28 standards.

We will send you soon a proposal which will give a detailed cost estimate for carrying out the recommended course of action.

Sincerely yours,

Richard A. Schleusener
Director

RAS:ry
cc: W. R. Sand
W. G. Myers
P. H. Wyckoff

bcc: J. N. Simmons
H. R. Fraser

MEMORANDUM FOR THE RECORD

FROM: W. R. Sand

SUBJECT: T-28 Options to date

SUMMARIZES: Trip to Pensacola 4-7 August 71
Trip to Davis Monthan 10-12 August 71

INFORMATION ON VARIOUS POSSIBLE OPTIONS.

I. Repair Our Aircraft at NARF Pensacola.

A. Some Service Changes need be incorporated.

B. Some Local Engineering Specifications should be incorporated.

C. Structural Modifications.

1. Wing Station #75 at a cost of about $2700. This modification gives more strength to the wing during negative G's.

2. Fuel system modification at a cost of approximately $1500.

3. Nose gear torque box & firewall modification to accommodate an 1820-86A engine. Parts for this job are about $5000. Labor costs are about $6700. (This dollar value includes the cost of an engine installation.)

4. Obtain an 1820-86A engine.

No-trade cost for this engine is between $30,000 & $50,000 to buy outright from the Navy. If we have an engine to trade in for QEC (quick engine change) unit the cost would be approximately $10,000.

D. Complete PAR overhaul at Pensacola would cost approximately $30,000. However, this cost estimate is considerably higher than the actual price to do our aircraft. Our T-28 doesn't need a complete Navy overhaul.

E. Dismantle our aircraft and ship to Pensacola.

F. A new prop would be required with the -86A engine at a cost of $4470 to purchase outright from the Navy.

G. There may be a requirement to install a speed-break system on our aircraft. If the money were available this would be highly desirable while the aircraft was going through PAR at Pensacola.

II. Obtain a T-28B from the Navy.

A. If the Navy will sell this aircraft to us outright, it would be at a cost of approximately $142,000.

B. It may be possible to obtain one of these aircraft through official channels at Washington. This may be possible at no cost.

C. It may be possible to purchase a new T-28C from North American at a cost of $242,000. This is the cost to the Navy.

D. Armor the new aircraft at a cost of about $6,000.

E. Install our radio gear at a cost of about $700.

F. Install our deicing for propeller and carburetor. This is the alcohol deice system. The cost would be minimal.

G. Install our instrumentation package in the new aircraft. This job could be done locally.

III. Obtain a T-28B surplus from Davis Monthan AFB.

A. The aircraft possibly available would only be suitable for parts and engine trade-in value on a good "0" time engine from the Navy.

B. This aircraft has been extensively cannibalized and all that remains is the basic fuselage (less wings), a high time prop, & most of the engine which is also very high time. The engine has 1100 hours plus, the prop has 1500 hours plus.

C. The U. S. Navy does not want to release this aircraft since it is the only salvageable hulk available to them and they are using it very extensively for spare parts.

D. The airframe is high time, 9,100 hours. The airframe is on a second extension for PAR overhaul.

1. This means that it has had roughly 37 months of service averaging 50 hours per month or approximately 1800 hours since it has been overhauled.

IV. Visit to Hamilton Aircraft at Tucson.

A. Mr. Gordon Hamilton, President of Hamilton Aircraft seems very willing to do a rework and modification job on our aircraft.

B. Hamilton Aircraft has an extremely good reputation for doing good work and holds an early STC on T-28's. They at one time worked over a number of T-28's under this STC. Current work centers around a turbo prop conversion on twin Beech aircraft known as a Westwind conversion.

C. A rough quote of $19,500 was given by Mr. Hamilton to work on our aircraft.

1. This would include a beef-up of the nose, but not a complete replacement of the torque box.

2. He would obtain and install an 1820-87 engine with a 300 hour guarantee and a 1000 hour warranty. This would probably come from Steward Davis of California.

3. This would include a fuel system fix on our aircraft.

4. This would include an x-ray check for any structural damage to the aircraft.

5. The bulk of the cost would be utilized for a general overall inspection and servicing of our airframe ($10,500). The other $9,000 would go towards obtaining and installing a -87 engine.

6. The actual cost may be slightly higher but we believe he would do a very good job on the aircraft.

7. Hamilton would only rework what had to be taken care of and those areas specifically requested by us.

OPTIONS AVAILABLE

I. Fix Our Aircraft.

A. Airframe

1. The cost to have Pensacola repair and check over our aircraft is dependent upon estimates by Mr. Donaldson (he'll be in Rapid City, 16 August to take a survey of our plane and determine what needs to be done.) The cost for the overhaul would be a minimum of $15,000. Having the Navy rework our airplane would guarantee that everything needed would be done and possibly more.

2. Hamilton Aircraft would check our airplane for any cracks with x-ray and generally give it an inspection fixing anything minor that needed to be fixed for a cost of about $10,500.

B. Engine

1. We can buy an 1820-86A engine outright from the Navy for approximately $30,000 to $50,000.

2. We can trade a run out engine to the Navy and obtain a "0" time engine for about $10,000.

a. We must obtain a run out engine to exercise this option, the run out engine may come from the U. S. Navy surplus at Pensacola or from surplus at Davis Monthan.

3. Hamilton Aircraft could furnish us an 1820-87 engine with 1000 hour service warranty and an unconditional guarantee of 300 hours from Steward Davis of California at cost of about $9,000. (Outright cost with no trade.)

C. Propeller

1. Buy a propeller from the Navy outright at a cost of $4470 for an 1820-86A engine.

2. Obtain a surplus propeller from Davis Monthan and trade it for a fresh overhaul prop from the Navy at a cost of approximately $1000.

3. Repair our prop or trade for a fresh overhaul prop since ours has at least one bad blade. This propeller is for the 1820-87 engine and should be repaired by Hamilton Standard or a good prop shop.

II. Obtain another T-28.

A. Acquire at no cost a T-28B from the U. S. Navy fresh out of PAR with a low time airframe (less than 3000 hours) and low time engine (less than 300 hours).

1. This would need to be done at the Washington level by NSF and the Navy.

B. Purchase a T-28B if one can be located. The cost would be between $40,000 and $142,000.

1. This is either from the U. S. Navy or civilian registry but in either case we would need be very careful here.

2. In any case this **aircraft** would need to be modified with armor plating, radios, etc. Cost for these modifications is on the order of $10,000.

III. Switch Aircraft to an EA-1

A. These aircraft are now readily available on the surplus market.

B. The aircraft is a large single engine machine using an R-2800 engine with a service ceiling of about 33,000 feet. It is slow and very strong.

C. Armor is necessary here too. Additional engineering would be required to armor this aircraft.

SUGGESTED OPTIONS IN ORDER

I. Obtain a T-28B for nothing from the U. S. Navy with airframe time less than 3000 hours and engine time less than 300 hours. This aircraft needs to have recently completed a PAR overhaul. We would need to modify this aircraft to do our job. The cost of this option would range from $10,000 to $150,000, depending upon where we obtain this aircraft and if we could get the basic aircraft at no cost.

II. Send our aircraft through Pensacola NARF for a complete rework, overhaul and modification to take an 1820-86A engine. This would cost from $25,000 to $80,000.

III. Send our aircraft to Hamilton Aircraft at Tucson for a complete inspection, install some beef up, and install an 1820-87 engine. This would cost approximately $19,000 to $30,000.

IV. Obtain an EA-1 and start all over again. Cost here would be at least $30,000 and could go up considerably. These aircraft have the advantage that they are very available at the present and we could get a good one with spares from surplus.

CC: R. A. Schleusener
A. S. Dennis
J. N. Simmons
W. G. Myers
M. J. Flannagan

APPENDIX B: Summary of Beechcraft Baron Operations During 1971

NHRE LOG 1971 SEASON
9677Y - Wayne Sand

9 July	5.4 hrs-CYS-RAP-first day on station. Worked in hailstone area with radio and radar checks for NCAR. Work with FAA on IFR flight plan in hailstone area.
10 July	RAP-weekend
11 July	RAP-weekend
12 July	2.4 hrs. RAP-LAR-GRE-LAR-flew to LAR to see U. of Wyo. Took Musil to GRE.
13 July	1.2 hrs-LAR-RAP-meeting at Grover. Decided to seed eight cases. Four below cloud and four feeder cloud.
14 July	RAP-worked on A/C inst. package and A/C problems.
15 July	5.3 hrs-RAP-CYS-RAP-Dr. Schleusener to CYS-Test case, no seed. Flew formation with U. of Wyo. C-45.
16 July	1.7 hrs-RAP-CYS-JEFCO-Prepare for weekend operations, store flares and base at JEFCO.
17 July	JEFCO-Standby for possible test case. No Go.
18 July	1.7 hrs. - JEFCO-RAP- No Go.
19 July	1.8 hrs-RAP-GRE-CYS-set up operations at CYS. Musil to GRE. No Go.
20 July	CYS-Meeting at Grover. Decided all seeding to be cloud base.
21 July	1.2 hrs. CYS-GRE-CYS-false alarm test case. No Go after airborne, dropped extra flares at Greeley.
22 July	2.9 hrs-CYS-GRE-CYS- Radio check A.M. with Ackley Smith of NCAR. Seed P.M. two groups. 23 flares total.
23 July	1.1 hrs-CYS- scramble. No Go. Drove to Grover for a meeting.
24 July	2.5 hrs-CYS-RAP-CYS-standby No Go. Flew Musil to RAP.
25 July	CYS-data problems noted. At each flare fire or advance the DL-620 stepped in time.

26 July	0.6 hrs-CYS- check flare fire problem rectified-fired 4 flares.
<u>27 July</u>	1.5 hrs-CYS-Vertical <u>Sounding</u> calibration flight.
<u>28 July</u>	3.2 hrs-CYS-Two <u>seed</u> cases-48 flares. Hail search flight.
29 July	1.2 hrs-CYS-RAP-flew to RAP for a T-28 meeting. Picked up Boardman, return CYS.
30 July	4.5 hrs-RAP-CYS-GRE-CYS-JEFCO-RAP Return CYS with Boardman. Pick up extra flares at GRE. Return all equipment and pay all bills at CYS. Return truck to JEFCO. Return RAP.
<u>31 July</u>	1.5 hrs. - RAP <u>calibration</u> flight on rate of climb and temperature.

APPENDIX C: IAS Report 71-15: **National Hail Research Experiment Revised Seeding Procedures - 1971**

Report 71-15

July 1971

National Hail Research Experiment Revised Seeding Procedures - 1971

By: Dennis J. Musil

Prepared for:

National Center for Atmospheric Research
P. O. Box 1470
Boulder, Colorado 80302

Institute of Atmospheric Sciences

South Dakota School of Mines and Technology

Rapid City, South Dakota 57701

CLOUD SEEDING - NHRE, 1971

1. INTRODUCTION

In July 1971, the Institute of Atmospheric Sciences (IAS) of the South Dakota School of Mines and Technology will provide a Beechcraft Baron aircraft for use as a platform for injecting nucleant into the volume of cloud and at the time considered best for optimum effects. The maneuverability of the aircraft in delivering nucleating agents at a specified time and place, plus possible seeding effects, will be evaluated.

The aircraft will be equipped with adequate NAV/COM equipment for IFR flight, a standard L-band transponder and DME, and an X-band transponder to permit tracking of the aircraft in precipitation with the NHRE M-33 located at Grover.

The aircraft will have a flight duration of approximately 4 hours and will carry 24 pyrotechnic flares on wing racks. Each flare carries 50 g AgI and burns in 20 seconds with an efficiency of about 10^{12} nuclei per gram AgI effective at -10C. The flares are manufactured by Olin Corporation (Formulation WM 106) and are on hand at Cheyenne, Wyoming. The objective is to deliver the nuclei at an altitude where the cloud temperature is -2C in the major updraft.

Personnel will consist of a meteorologist located in Grover, who will coordinate the seeding missions, a pilot for the seeding aircraft (which will be located at Greeley) and a technician-observer.

2. PROCEDURES

A decision whether or not to attempt to seed will be made by the NHRE Operations Director. The decision will be relayed to the IAS meteorologist at Grover, who will scramble the seeding aircraft and direct the pilot towards the test storm. During the flight, the Baron will be under the control of Greeley radar, although the pilot and IAS meteorologist at Grover can maintain communication via 123.05 mhz.

Grover radar will monitor the maximum reflectivity in the storm and at the 30K ft level. The 30K ft level is selected because it is believed that new hail bearing cells are detectable by radar at this level. At the same time, the major updraft will be located and measured at cloud base by the Wyoming C-45.

2.1 Types of Seeding

Types of seeding procedures can be classified into three categories as discussed below:

Inside Parent Cell (IPC) - This type of seeding is the same as was proposed originally for the T-28. It will be concentrated on mature front feeding storms expected to propagate east of the mountains in the western half of the experimental area and will involve penetrations of the cloud at an altitude corresponding to a temperature of -2C. (This can be estimated by adjusting the altitude of the seeding aircraft to a temperature of -5C ambient air temperature outside the cloud.) A flow diagram showing the sequence of events leading to a penetration is given in Fig. 1. Several Go/No-Go decisions must be made prior to a penetration.

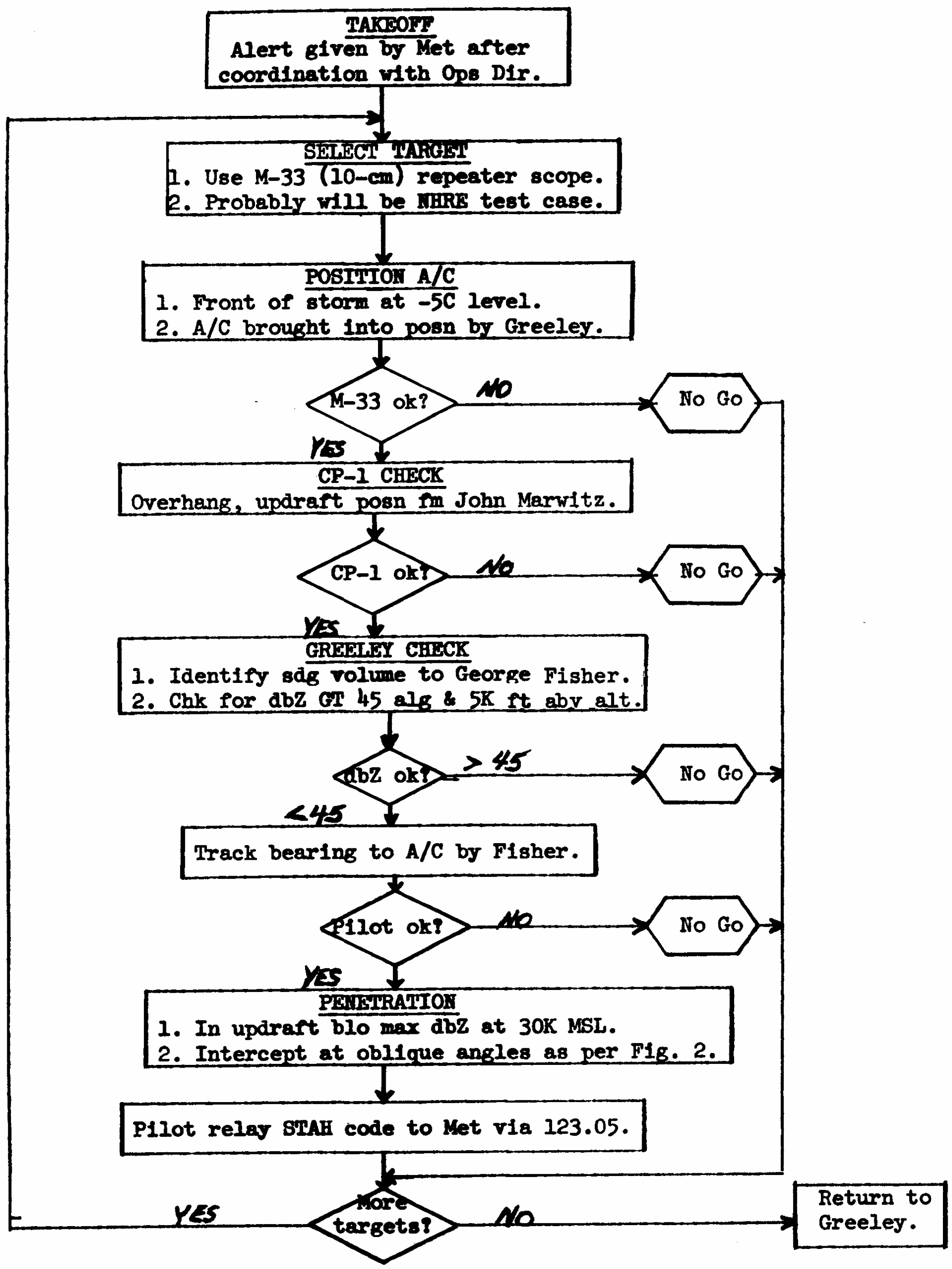

Fig. 1. Flow diagram showing decision-making process leading to a penetration of a mature thunderstorm.

An attempt will be made to vector the seeding aircraft through the major updraft below the max Z at 30K ft. It is felt that the safest means of penetrating a mature thunderstorm with a thin-skinned aircraft is to intercept the updraft at oblique angles as shown in Fig. 2. The coordinates of the max Z at 30K ft and the track bearing will be given by the IAS meteorologist at Grover to the aircraft controller at Greeley to enable him to vector the seeding aircraft into the desired position. After cloud penetrations have begun, the pilot will begin seeding as soon as updrafts exceeding 1000 fpm are encountered. The CSU F-101 should make nearly simultaneous penetrations near cloud top.

Initially, 20 flares (1 kg AgI) will be burned on one pass in order to increase the probability of observing seeding effects on radars and aircraft through one large pulse of nucleant. Other treatment rates may be used later in the season.

Due to aircraft safety considerations, in view of the danger involved with penetrating mature thunderstorms, certain restrictions must be imposed on IPC seeding. First of all, because the Baron aircraft is not armor plated, if hail is encountered, a 180° turn will be made to avoid structural damage to the aircraft. Secondly, it is necessary that the computer display system works properly, so that at least CAPPI displays and aircraft position at penetration altitude, plus flight track, are available on a "quasi" real-time basis. Third, it is necessary that this type of seeding be carried out after experience is gained in working with the radar display systems and confidence is gained in its use. Practice sessions are planned, with no actual penetrations being made during the first several days. Furthermore, in line with recent information, it is felt that regions with reflectivity measurements

PLAN VIEW

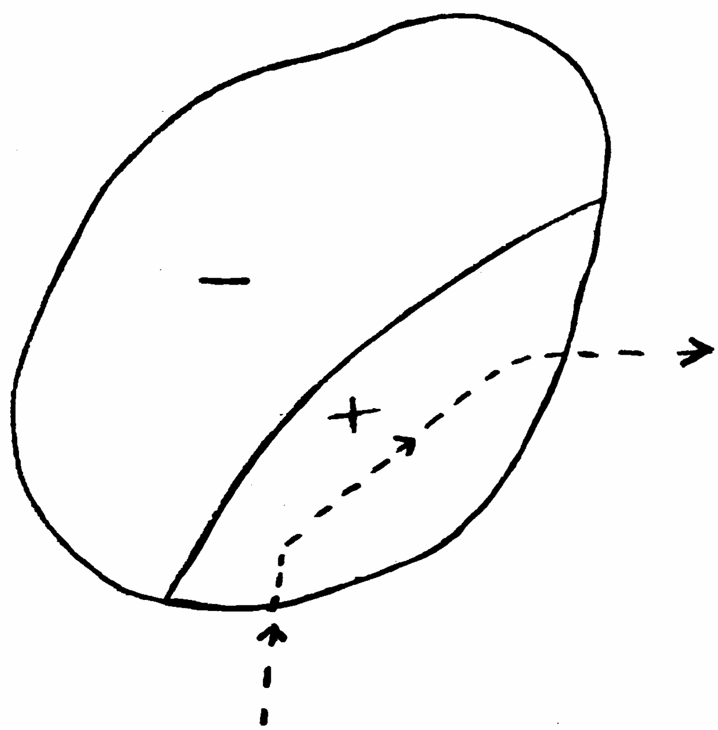

Fig. 2. Planned flight track of Baron in radar echo of a mature thunderstorm. Plus sign indicates updraft and minus sign indicates downdraft. Dashed line is proposed flight track.

greater than 50 dbZ from a well calibrated 10-cm radar system should not be penetrated with a Baron aircraft.

Feeder Cloud (FC) - This seeding will take place in the feeder clouds associated with some storms. These new towers can be seeded at the -2C level by penetrating the towers or by seeding below their bases in the updrafts. A flow diagram showing the decisions leading to a penetration of a feeder cloud is given in Fig. 3. It is expected that feeder clouds can be penetrated with no prior practice.

Seeding amounts and techniques should remain flexible, since they will depend on the size and duration of the feeder cloud. Visual navigation is expected to be necessary, since the new towers will not always exhibit a radar echo.

Below Cloud Base (BCB) - As in IPC seeding, these missions are carried out on mature front feeding storms; however, the seeding is done below cloud base in the vicinity of the roll cloud. The seeding material will be placed in the major updraft and should reach the -2C level in approximately 2 min. The relationship between the major updraft and max Z at 30K ft is essentially the same as for IPC seeding, but without the possible hazards involved in penetrating a mature storm.

2.2 Observations

A portion of the data system originally on the T-28 and described in Report 71-13, Armored Aircraft Work Plan, May 1971, has been placed aboard the Baron. It will provide parameters such as liquid water, vertical velocity and aircraft position in digital form on magnetic tape during penetrations. Plans for gathering and handling of these data are the same as given in the T-28 work plans. This includes use of portions of the STAH code form (Fig. 4), which will be modified as appropriate in order to fit the mission of the Baron aircraft.

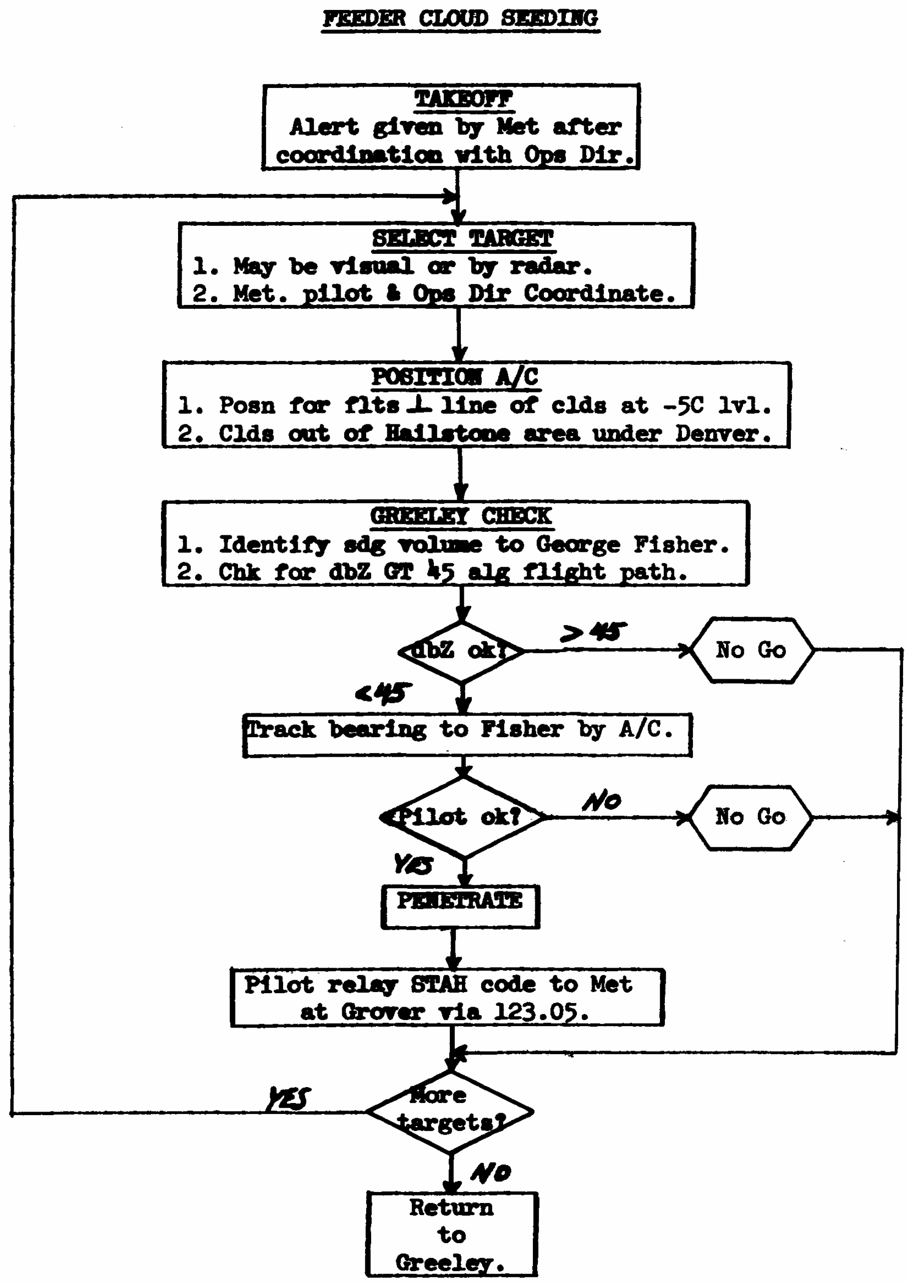

Fig. 3. Flow diagram showing decision-making process leading to a penetration of a feeder cloud.

In addition to data being gathered by various aircraft involved with the NHRE project, the ground teams will be informed of the time and location of seeding and will be requested to take precipitation samples for AgI analysis. Visual observation can be made by the pilot and technician-observer aboard the seeding aircraft.

2.3 Flight Safety

Decisions dealing with flight safety must be left to the pilot's discretion. Penetrations felt to be unsafe will not be made. As noted above, 18180° turn will be made if hail is encountered on any seeding pass.

2.4 Personnel

Individuals involved with the field phase of the project are:

Name	Title
Dennis J. Musil	Meteorologist
Wayne R. Sand	Pilot
Kenneth E. Jasper	Technician-Observer

National Hail Research Experiment
Beechcraft Baron

Date ______________

STAH CODE FORM

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

Fig. 4. Form to be used by IAS meteorologist at Grover to record information concerning penetrations. Since this form was prepared for use with the T-28, parts of it may no longer apply to the Baron seeding mission.

APPENDIX D: Personnel Cost Breakdown

LIST OF PERSONNEL ASSOCIATED WITH THE CONTRACT

1 May 1971 - 30 April 1972

Name	Title	Months Worked Under Referenced Contract
Professional		
Richard A. Schleusener	Director	1.75
James H. Boardman	Junior Research Engineer	.02
Arnett S. Dennis	Head, Meteorologist Analysis Group	.08
John H. Hirsch	Research Meteorologist	1.28
Gary N. Johnson	Junior Research Engineer	.68
Dennis J. Musil	Research Meteorologist	4.07
William G. Myers	Research Engineer	5.46
Garth Peterson	Mathematician Programmer	.10
Wayne R. Sand	Pilot	11.86
Paul L. Smith	Head, Engineering Group	.36
		25.66
Technical Staff		
Wallace D. Amborn	Assistant Chief Electronics Technician	.45
Leonard N. Block	Aircraft Mechanic	3.88
Melvin J. Flannagan	Pilot Technician	.27
Kenneth E. Jasper	Electronics Technician	9.57
		14.17
Undergraduate Students		
Robert Buchanan		.23
John Callahan		.06
Stephen F. Isaacson		.11
Dennis Johnson		.21
Roman L. Zylla		.37
		.98
Others		
Karen Brown	Secretary	.27
Joie L. Robinson	Secretary	.47
Ramona M. Young	Secretary	.16
		.90

Total Man-months 41.71