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UMRI PROJECTS 2451-1 AND 2451-2 REPORTS, 1958-1959

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Reprinted herewith are the reports describing the work performed under Contract No. NOrd-16595 (University of Michigan Project 2451) during the period 1958 through 1959. The work under this contract has consisted of two unrelated tasks. One was an investigation of variations in the earth's magnetic field due to solar activity; the other was a wind-tunnel study using various side-jet configurations at varying Mach numbers.

At the suggestion of the cognizant officers at the Applied Physics Laboratory, the reports of both tasks are here reprinted under one cover.

In the future, reports on the two tasks will be issued quarterly; they will continue to be submitted under the same covers.

UMRI PROJECT 2451-1

STUDIES OF VARIATIONS IN THE EARTH'S MAGNETIC FIELD  
DUE TO SOLAR ACTIVITY



JANUARY 1 TO MARCH 31, 1958

#### PERSONNEL

Mr. Donald Royal, who was hired in December for work on this project, left in early February for a position at a higher salary and of a more permanent nature. It has not yet been possible to find a suitable replacement.

#### INSTRUMENTS

The magnetometers continue to record reasonably well, and the WWV recorder continues to provide excellent records of ionospheric effects at the time of flares.

#### GEOMAGNETIC EFFECTS DURING THIS QUARTER

The great geomagnetic storm of February 10, 1958, was well recorded on the total field variometer and the 18 Mc/s cosmic noise recorder. The storm was so severe that the declination magnetometer was "off scale" during most of the disturbance.

#### STUDIES IN PROGRESS

Crochets.—The study of crochets mentioned as "in progress" in the preceding Quarterly Report has been considerably extended. We have found, quite unexpectedly, that flares associated with crochets have an atypical disk distribution. This result has caused us to explore further the properties of crochet-associated flares. The study is approaching, but has not yet reached, the form in which we want to publish it.

#### ABSORPTION OF 18 Mc/s COSMIC RADIATION AT THE TIME OF SEVERE GEOMAGNETIC STORMS

We have made an effort to compare details of the variations in 18 Mc/s absorption with variations in the "total" component of the geomagnetic field recorded at Lake Angelus for two severe geomagnetic storms. We selected for the exploratory investigation the storms of September 13, 1957, and February 10, 1958, since they took place at times similarly placed with respect to local midnight and had similar durations. In addition we have brought together geomagnetic and 18 Mc/s records for a relatively minor disturbance on February 12, 1958.

The geomagnetic and 18 Mc/s records do not lend themselves readily to di-

rect comparison because of the differences in time scales of the recorders and the fact that the "ordinate" is curvilinear in one case and rectilinear in the other. Through "manual" copies on tracing paper, and subsequent "lantern" projections we prepared "enlargements" of the curvilinear geomagnetic records which have the same time scale as the 18 Mc/s records. Small inaccuracies have been unavoidable in this process. Consequently, care should be taken lest the data be overinterpreted. The investigation to date suggests the following information and tentative relationships.

1. Severe geomagnetic disturbances are associated with deep and rapidly varying 18 Mc/s absorption, but minor geomagnetic disturbances cause either no measurable event on our records or only an inconspicuous absorption feature.

2. Within the accuracy of the present comparison, the times of rapidly increasing 18 Mc/s absorption coincide with the times of rapidly changing magnitude in the total component of the geomagnetic field.

3. Intervals of very great 18 Mc/s absorption coincide with intervals in which the total magnetic component was either rapidly changing magnitude, or was very much greater in magnitude than its normal value and with the magnetic "sense" represented by the lower half of our records.

4. Frequently, conspicuous diminution in the abnormal 18 Mc/s absorption occurred when the magnetic component was approaching its normal value, or was passing through this value to a large displacement with the magnetic "sense" represented by the upper half of our records.

5. During both of the great storms here studied, there were intervals of half hour to an hour in which the magnitude of the magnetic component remained much greater than normal, with the "sense" of the upper part of our charts. During these intervals, excess 18 Mc/s absorption, though present, was not great.

6. For the September 13, 1957, storm there was no measurable change in 18 Mc/s absorption at 00<sup>h</sup>46<sup>m</sup>, the reported time of start of the "sudden commencement." The first 18 Mc/s absorption on this date occurred a few minutes before 03<sup>h</sup> when the magnetometer took its first swing in the negative direction.

On February 10, 1958, the first deep 18 Mc/s absorption was recorded at 02<sup>h</sup>11<sup>m</sup>, five or more minutes after the first great negative swing on the magnetometer. However, on this date the 18 Mc/s record **showed an** unusual "emission" feature starting at 00<sup>h</sup>30<sup>m</sup> and continuing until 02<sup>h</sup>11<sup>m</sup>.

7. Comparison of the 18 Mc/s-cosmic-noise and total-field-magnetometer records for these two storms has created an impression that circumstances or relationships are slightly different either before and after midnight, or in the first half and second half of the storm.

The accuracy and generality of the relationships here suggested must be checked by study of records for other severe geomagnetic storms.

APRIL 1 TO JUNE 30, 1958

#### PERSONNEL

Mr. Robert Gouin was hired in May for work on this project.

#### INSTRUMENTS

The magnetometers continue to record reasonably well and the WWV recorder continues to provide excellent records of ionospheric effects at the time of flares. In addition there is evidence that two series of 27-day recurrent storms may have developed. These storms are of longer duration and show less direct relation to observed solar activity. The 27-day recurrent storms are characteristic of the declining branch of the 11-year cycle of solar activity and their existence now (if true) is unexpected.

#### STUDIES IN PROGRESS

Our 18 Mc/s cosmic radiation records are being examined for evidence of increased absorption at the time of all geomagnetic disturbances. As stated in the preceding Quarterly Report the long intervals of great absorption occur only during severe storms. Nevertheless, the present investigation indicates that there are numerous examples of well defined, though sometimes brief, intervals of moderately great absorption in close time association with the brief interval of maximum disturbance in less severe geomagnetic storms.

#### STUDIES COMPLETED

We have completed as part of our normal solar research at the McMath-Hulbert Observatory a study of crochet-associated flares. This study may have interest for those who are concerned with the earth's magnetic field since the crochet, though minor, is a variation in the earth's magnetic field. The study has been sent to the Astrophysical Journal for publication and a pre-publication copy of the manuscript is being sent to Dr. Alfred Zmuda via Mr. Paul Schwartz's office.

JULY 1 TO SEPTEMBER 30, 1958

#### PERSONNEL

Mr. Robert Gouin is still employed under this contract as an assistant at the observatory.

#### INSTRUMENTS

The magnetometers continue to record reasonably well and the WWV recorder continued to provide excellent records of ionospheric effects at the time of flares.

#### STUDIES IN PROGRESS

Our main effort during the summer quarter has been observational. The principal observing programs have centered on flare spectra and on photographic records of wavelength sweeps across centers of activity on the solar disk. These observations may be of assistance in understanding why some flares do and other flares do not cause concomitant changes (crochets) in the earth's magnetic field. It is already clear from the observational data that sudden, temporary brightenings on the solar disk (all well deserving of the designation, flare) may have very different spectra.

Our study of Crochet-Associated Flares has been accepted for publication in the November issue of the Astrophysical Journal.



OCTOBER 1 TO DECEMBER 31, 1958

#### PERSONNEL

Mr. Robert Gouin who was employed under this contract was called for military service in early October, and left. Arrangements have now been made for Mr. Bernard Adams to start work on this project early in January, 1959.

#### INSTRUMENTS

The declination magnetometer loaned to the McMath-Hulbert Observatory by APL for use on this project was returned to APL on October 31, 1958. The total field variometer continues to supply good records of the more severe disturbances of the earth's magnetic field. The WWV recorder is working well.

#### STUDIES IN PROGRESS

Since no one has been employed on this contract during most of the last three months, there has been but little direct work on the project. However, plans have been made to carry out in the months ahead two studies that are directly related to the purpose of this project, (1) an investigation of solar circumstances at the times of BEGINNING of the great 27-day sequences of recurrent geomagnetic storms, 1950-54; (2) an evaluation of the most probable solar causes of the geomagnetic storms that took place during the IGY.

Both studies are long and require organization of a vast amount of observational data. It is our hope that Mr. Adams will be able to assist us, especially, in the first of these projects.

Our study of Crochet-Associated Flares appeared in the November issue of the Astrophysical Journal, 128, 636, 1958. When reprints of the article are available, one will be sent to Dr. Zmuda.

JANUARY 1 TO MARCH 31, 1959

#### PERSONNEL

Mr. Bernard Adams who was employed in January to work on this project proved to be unsatisfactory both for direct work on the project itself and for other work in the observatory that could be accepted on an "exchange time" basis. Accordingly, arrangements were made for his return to UMRI where he had been employed prior to his transfer to Lake Angelus.

Mr. Frederic Stewart was employed to work on this project starting March 1, 1959, and is proving to be satisfactory.

Obligations and commitments of the regular staff of the McMath-Hulbert Observatory are now such that they can supervise, but not work directly on this project for long periods of time as they have done in the past. Therefore, in order to make progress on the project it is necessary for us to be able to employ someone capable of doing the type of work involved in the analysis. We believe that Mr. Stewart will be able to do this.

#### INSTRUMENTS

The total field variometer continues to supply usable records of the more severe disturbances of the earth's magnetic field. Records of variations in the strength of the 5 Mc/s WWV signal have been improved through installation of a new aerial.

#### STUDIES IN PROGRESS

In order to evaluate the most probable causes of geomagnetic storms during the IGY, it is necessary to have a definitive list of flares based on world-wide observations. During the quarter in question, Miss Ruth Hedeman of our own professional staff has given much of her time to the inter-comparison of flare reports from "world-wide" solar observatories, and to the preparation of the needed list of flares. Therefore, even though the person employed on this contract for most of this quarter was not satisfactory, work has been done on the project.

After the list of flares has been prepared, it will be necessary to evaluate the solar radio frequency emission and the geomagnetic data, both of which constitute long tasks. At the present time we are far from being ready to report on the problems undertaken by the project, but we are making progress.

APRIL 1 TO JUNE 30, 1959

#### PERSONNEL

Mr. Frederic Stewart is employed on this project.

#### INSTRUMENTS

The total field variometer and the 5 Mc/s WWV recorder continue to provide useful records.

#### STUDIES IN PROGRESS

As of June 30, 1959, the working list of IGY flares was completed for the first 13 months of the IGY.

In order to assist in the evaluation of the geomagnetic effects of various flares during the IGY, we need to be able to examine certain radio-frequency records. During a series of visits in March and April, 1959, to IGY solar stations in Western Europe, Dr. Helen Dodson Prince expressed this need to Ir. H. H. de Voogt, Director of NERA, in The Hague. Ir. De Voogt and his colleagues at NERA have most graciously agreed to send to the McMath-Hulbert Observatory copies of their original 200 Mc/s records, for the entire 18 months of the IGY. Because of their three similar stations at The Hague, Paramaribo and Hollandia NERA has 200 Mc/s solar data for 24 hours of the day. This is the only 24 hours coverage of this type available, and we look forward to detailed examination of the records in the coming months. Records for three months of the IGY have already arrived from Holland.

JULY 1 TO SEPTEMBER 30, 1959

#### PERSONNEL

Mr. Frederic Stewart is employed on this project.

#### INSTRUMENTS

The total field variometer and the 5 Mc/s WWV recorder continue to provide useful records.

#### STUDIES IN PROGRESS

The working list of IGY flares has been completed. More than 6000 flares were observed and reported by the world-wide HQ flare-patrol stations during the 18 months of the IGY. First efforts to compare the IGY flare data with the world-wide ionospheric data, as assembled at CRPL of NBS, for the same time interval revealed that both sets of data are seriously non-homogeneous with respect to Universal Time. In order to be able to use the IGY flare data as a basis for the study of geomagnetic storms it is necessary to take this lack of homogeneity into account. Accordingly, we studied the world-wide flare data until we understood at least certain of the causes of the very large number of flares reported for 05<sup>h</sup> to 16<sup>h</sup> U.T. The results of our survey have been prepared for publication and are scheduled to appear in the January, 1960 issue of the Journal of Geophysical Research.

Studies are now in progress of three great flares which are thought to have been closely associated with three great geomagnetic storms, increased cosmic rays in the neighborhood of the earth, and with strong continuum and centimeter radiation at radio wavelengths. We are trying to discern, from our optical records, features that distinguish these flares from other great flares without these special accompaniments.

UMRI PROJECT 2451-2

JET TASK



JANUARY - JUNE 1958

The interaction between a two-dimensional side jet and a supersonic main stream has been calculated by a more accurate theory than that developed previously. The improved method predicts much larger favorable interaction effects, so that in certain cases an airfoil equipped with jet flap can be shown to produce a certain amount of lift with a smaller total expenditure of jet thrust than does the same airfoil at an angle of attack but without side jet.

An example of two-dimensional side jet interaction calculated by the more accurate theory is shown in the accompanying figure. The shape of the jet was found by the method of characteristics, assuming no mixing of the jet gas with the separated flow regions on either side of it. The pressure in each of the separated flow regions was assumed to be constant; in the downstream region the base pressure was taken to be 0.3 of the stream static pressure. The Reynolds number was assumed to be low enough that the mixing layer at the edge of the upstream dead air region would be laminar and remain laminar after reattachment. The reattachment equation derived and experimentally verified by Chapman, Kuehn, and Larson for the case of no boundary layer thickness at separation was used to find the reattachment point.

For the example shown, the lift coefficient based on total lift was found to be  $C_L = .500$ , and the total thrust required to overcome pressure drag and to maintain the jet flap was .373 pound per pound of lift (skin friction drag was neglected). For comparison, the same airfoil without jet flap and at an angle of attack that would give the same lift coefficient would require .435 pound of thrust per pound of lift, to overcome pressure drag. The interaction force predicted by the more accurate method was found to be about 8 times as large as that given by the crude theory.

Experimental work will be resumed soon with tests to determine whether the  $M = 3.9$  data are affected by windshield interference. Tests of inclined, multiple, and slotted side jets will follow.

JULY - DECEMBER 1958

Tests of several side jet configurations were made at Mach number 3.9, as reported at the 39th Regular Meeting of the Bumblebee Aerodynamics Panel. These tests utilized a smaller windshield than the previous tests, and the resulting reduction in support interference gave normal force magnification factors which were considerably larger than those measured previously. Multiple jets and forward-inclined jets gave somewhat smaller magnification factors than the single normal jet. A nose jet was much less effective than the aft jets.

In order to evaluate more accurately the performance of the various side jet configurations, a new hollow sting balance of greater sensitivity has been constructed. On this sting the strain gages are located within the model, so that no windshield is necessary. Support interference should therefore be reduced to a minimum. A new adapter allows the existing models to be tested on the new balance.

Some of the previously-tested configurations will be re-tested on the new balance. New configurations to be tested include aft-inclined jets, various jet diameters, non-circular jets, and supersonic jets. Effects on stability with jets exhausting all-around at either of two axial stations will also be determined.



JANUARY - JUNE 1959

A hollow sting balance of greater sensitivity than the sting balance used prior to the period covered by this report, has been constructed and calibrated. The new sting was designed so that the sensing elements of the sting were internal to the model, thus eliminating the need for a windshield and reducing the influence of the sting on the base pressure.

A test was conducted to determine the effects of circumferential air bleeding on the stability of a missile configuration. The tests were conducted at  $M = 2.43$  and the results were included in a University of Michigan internal report "Stability Tests on a Bleed Simulator at  $M = 2.43$ ," by Paul B. Hays, University of Michigan WTM 264, May 1959.

Side jet studies using the new hollow sting were continued during this period at Mach numbers 2.43 and 3.90. The following table presents the configurations and the Mach numbers at which they were tested.

Orifice, ( $d = .159''$ )	Distance from Base, Inches	Test Mach Numbers
Straight sharp entrance	.50	2.43
		3.90
Cone, $15^\circ$ half angle, throat $d = .159''$	.50	2.43
		3.90
Straight round entrance	1.125	3.90
$15^\circ$ inclined aft round entrance	1.125	3.90
$45^\circ$ inclined aft round entrance	1.125	3.90
Nose jet, inclined $14^\circ$ for- ward, normal to surface of model	9.604	3.90

The results of the tests at  $M = 3.90$  were presented at the 40th meeting of the Bumblebee Aerodynamics Panel. They were also included in a report to be presented at the joint meeting of the AGARD Wind Tunnel Panel and the Supersonic Tunnel Association (STA), Marseille, France, September, 1959, en-

titled "Interaction Effects of Side-Jets with Supersonic Streams—Experimental Results and Wind Tunnel Techniques," by H. P. Liepman.

The work planned for the future includes the following:

1. Preparation of a paper for publication in a technical journal covering all work completed to date.
2. Construction and testing of side-jet and fin configurations.
3. Investigation of roll-pitch-yaw coupling effects produced by tangential jets.
4. Simulation of a body flare by a circumferential slot and investigation of its effect on pitching moment.
5. Investigation of the effect of varying the ratio of specific heats on the interaction force produced by the side jets.

JULY - DECEMBER 1959

Preliminary tests have been made of a body of revolution having cruciform fins, with a side jet issuing between a pair of fins near the base. With this arrangement, the helpful interaction force was found to be approximately three times as great as on a body without fins. Further tests of finned bodies with side jets will be made following a reappraisal of the results for bodies without fins.

Studies were made of various gas mixtures suitable for determining the effects of varying the ratio of specific heats of the jet gas on the interaction force. Two mixtures have been found which would enable this effect to be evaluated, independently of the other gas properties.

Initial attempts to measure mass flow through the side jet have been successful in the upper part of the mass flow range. However, some additional equipment will be needed to measure the smaller mass flows.





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