Communications Research Centre

TWENTIETH TRI-ANNUAL ISIS PROGRESS REPORT FOR THE PERIOD 1 JULY TO 31 OCTOBER, 1969

DEPARTMENT OF COMMUNICATIONS
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COMMUNICATIONS RESEARCH CENTRE

DEPARTMENT OF COMMUNICATIONS

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NATIONAL SPACE TELECOMMUNICATIONS LABORATORY

TWENTIETH TRI-ANNUAL ISIS PROGRESS REPORT

FOR THE PERIOD

1 July to 31 October, 1969

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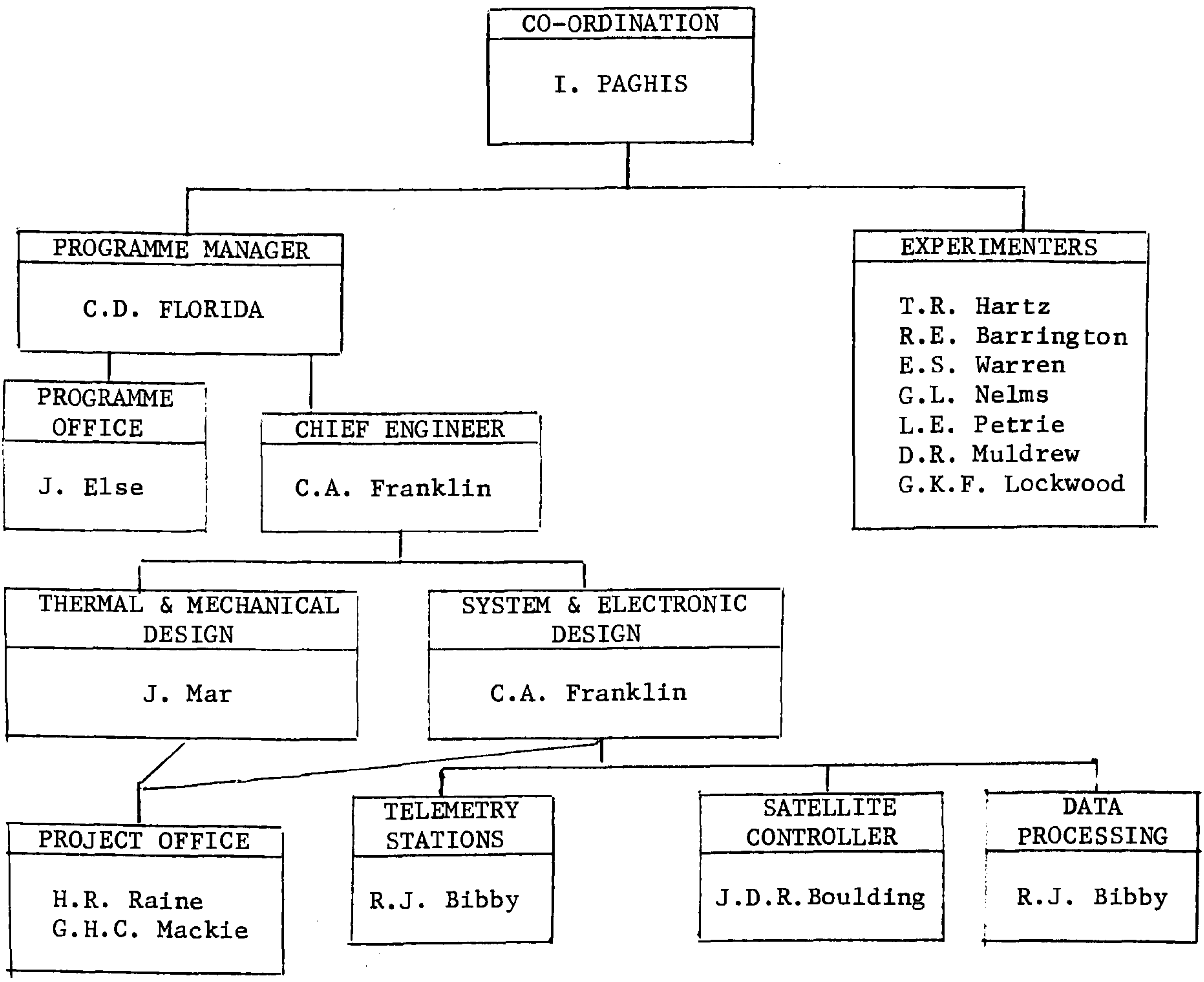
C O N T E N T S

TWENTIETH TRI-ANNUAL ISIS PROGRESS REPORT

1 July, 1969 to 31 October, 1969

CRC PROGRAMME ORGANIZATION



2. INTRODUCTION AND SUMMARY OF PROGRESS

On 29 September, 1969, Alouette I completed seven years of satisfactory operation. The satellite continues to provide sounder and VLF data for approximately 1-1/4 hours per day. No further changes in the status of this satellite have been reported.

Alouette II has now completed nearly four years in orbit and, except for the 300 watt power amplifier failure that was reported previously, all systems are operating normally. The spacecraft is currently providing data for 3-1/4 - 5-1/2 hours per day. The spin rate has decreased to 1.86 rpm.

An offer has been made to the international scientific community permitting ground stations in other countries to acquire data from Alouettes I and II.

The daily operating schedule of ISIS-I over the reporting period has been 6 hours per day in minimum sun and 9 hours per day in maximum sun. On 26 October, 1969, the SPS experiment developed a fault in the -4Kv power supply and became inoperative. Investigation of the problem continues and details of the findings will be reported later. Since early September, occasional speed changes have been observed in the operation of the on-board tape recorder. This indicates that ionograms produced from dumped tapes may have significant height errors unless special precautions are taken during data processing. The duration of the fixed frequency sounding period appears to have stabilised at about three seconds.

Integration of the ISIS-B prototype model spacecraft continues at the Contractor's plant in Montreal. So far, preliminary antenna matching and the integration of the power, command, telemetry, and attitude sensing and control systems has been accomplished without any significant problems. The direct measurement experiments and sounder system units are being integrated as they become available. The impact of the late delivery of the experiment packages on the overall schedule is giving some cause for concern. Although preliminary integration checks will be carried out using engineering model units of some experiments, several do not have these units available. The semiconductor problems in the clock and programmers have now been resolved and the schedule for these units has been improved. It has been decided to make the AGC characteristic of the sounder receiver steeper and less temperature dependent. This modification will be carried out on the flight model only because of schedule constraints. If the modification proves to be impracticable, a receiver with the ISIS-I AGC characteristic will be flown. The reinforcement of the upper auxiliary heat shield has now been completed. Vibration tests of the complete assembly, including the beacon and UHF antennae, and the upper CEP probe, will be carried out in the near future. It has been decided to replace the Dalmo Victor magnetometer with a potentially more reliable one developed by RCAL. The wiring harness on the flight model spacecraft is essentially complete. Units are being installed as they become available, but power has not yet been applied. The estimated weight for this model is 557 lbs. The current slip, based on the 21 December,1970 launch, is 11 weeks and the latest run of the CPM schedule predicts an ultimate slip of 22 weeks. This is predicated upon the delivery dates for overdue experiments. The main ground support equipment is now complete and has been moved into the integration laboratory. This allows integration to proceed simultaneously on both spacecraft.

J. Else.

3. ISIS-I

3.1 Satellite Characteristics

Orbit

Apogee	3522	
Perigee	574	
Inclination	88.42°	prograde
Spin	2.939	rpm
Period	128.3	mins.

Spacecraft Stabilization

Spin stabilized 1 to 3 rev/min.

Spacecraft Attitude Sensing

Six-probe flux-gate magnetometer	Four probes, range -600 to +600 millioersteds: z-y-z orthogonal set, and s probe along spacecraft x direction. Two probes, range -200 to +200 millioersteds: along spacecraft x and z directions.
Digital solar aspect sensor	Two sensors, each with 180° fan field of view; storage register in electronics.

Spin and Attitude Control System

Spin rate change capability 0.1 rpm/orbit.
Spin axis attitude manoeuvring capability 3°/orbit.

Power System

11,136 n-on-p 10-1/4% (A.M.O.) efficiency solar cells will charge 3 Ni-Cd batteries.
Six main system DC to DC converters.
Operational time after 1 year, minimum of 4 hours per day.
Continuous operation: Two consecutive pole-to-pole passes.

Command System

Command

Multiple tone-digital AM AVCO system.
2 receivers operating 148 MHz; 1 redundant.
Decoder capability--216 commands.

Programmer and Clock

Stored commands for remote turn-on execution.
Capability--5 remote turn-on from 10 commands.
Loading time 5 minutes.
Programme monitoring facility (readout time 3 secs.).
Clock output--serial time code BCD format 60 bps, once per second.
Ground correction capability.
Stability and accuracy 1 sec/week.

Automatic Turn-Off

Normal turn-off - after 16 mins.
Special turn-off - after 8 or 24 mins.
Programmed turn-off - after 16 mins.
Back-up - after 30 mins. unconditionally.
Spin and attitude control - 1^{+0}_{-1} and 5^{+0}_{-1} hours, selectable by command.

Tape Recorder

Record time - 65 mins.
Playback - 4 times record speed.
Data channels - 4.
(a) FM data - sounder output FM bandwidth 1 Hz to 9 KHz.
(b) Ref. Frequency 11.52 KHz + AM Time Code.
(c) Digital data 11,520 bits per sec.
(d) Analog data - VLF output bandwidth 50 - 20,000 Hz.

Telemetry

Transmitter No. 1

Frequency		136.080 MHz: bandwidth 100 KHz
Power		4 Watts
Modulation	FM	Sounder
	PAM/FM	SCO essential housekeeping and clock
	FM	VLF

Max. range for 10 dB S/N 3500 miles with 19 dB ground antenna gain.

Transmitter No. 2

Frequency		401.750 MHz: bandwidth 500 KHz
Power		4 Watts
Modulation	FM	Sounder
	PCM/FM/PM	SCO experimental data and housekeeping
	FM	VLF
	AM/PM	SCO satellite clock

Max. range for 10 dB S/N 3500 miles with 19 dB ground antenna gain.

Transmitter No. 3

Frequency		136.59 MHz: bandwidth 50 KHz
Power		2 Watts
Modulation	PCM/PM	Experimental data and housekeeping

Beacon

Frequency	136.410 MHz
Power	100 mw
Unmodulated	

Experiments

(1) Swept Frequency Sounder

Power output	400W at PRF 30/sec.
	100W at PRF 30/sec.
Antennas	240' and 61.5' tip-to-tip
Flyback	3 secs.

Frequency Range

(a) Normal Sweep 0.1 to 10 MHz

Frequency Range	Sweep Rate	Time to Cover Frequency Range
0.1 to 2.0 MHz	0.25 MHz/s	7.6 seconds
2.0 to 5.0 MHz	0.75 MHz/s	4.0 seconds
5.0 to 10.0 MHz	1.0 MHz/s	5.0 seconds
	Total time	16.6 seconds

Distance travelled about 75 Km at Apogee
about 125 Km at Perigee
Maximum change of height about 18 Km

(b) Extended Sweep 0.1 to 20 MHz

Frequency Range	Sweep Rate	Time to Cover Frequency Range
0.1 to 2.0 MHz	0.25 MHz/s	7.6 seconds
2.0 to 5.0 MHz	0.75 MHz/s	4.0 seconds
5.0 to 20.0 MHz	1.0 MHz/s	15.0 seconds
	Total time	26.6 seconds

Distance travelled about 120 Km at Apogee
about 200 Km at Perigee
Maximum change of height about 20 Km

(c) Sweep Law - Linear in all ranges.

(d) Frequency Markers

0.25, 0.5, 0.75. 1.0, 1.25, 1.5, 1.75, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0, 12.0, 14.0, 16.0, 18.0, 20.0 MHz.

(2) Fixed Frequency Sounder

The six frequencies selected for the fixed frequency sounder are 0.25, 0.48, 1.0, 1.95, 4.0, and 9.303 MHz.

Sounder Receiver Characteristics

Pre-amp. and filter No. 1, seven bands
(a) 0.1 - 1.0 MHz
(b) 1.0 - 2.0 MHz
(c) 2.0 - 3.0 MHz
(d) 3.0 - 5.0 MHz
(e) 5.0 - 8.0 MHz
(f) 8.0 - 13.0 MHz
(g) 13.0 - 20.0 MHz

Pre-amp. and filter No. 2 wideband 0.1 - 2.0 MHz.
Linear - logarithmic receiver with AGC loop characteristics.
Rise time 60 msecs. Fall time 12 msecs.

(3) VLF Receiver

0.05 - 30 KHz
Monitored AGC voltage
A VLF swept frequency exciter

Range 500 - 0 - 9500 Hz
Sweep rate at 50 Hz is 2 KHz/s
Sweep rate at 9500 Hz is 40 KHz/s
Sweep duration 1 second
Frame period 1.5 seconds
Output automatically sequences through two 20 dB steps.

(4) Energetic Particle Detectors (NRC)

Parallel to satellite axis

Detector G_1	> 40 KeV Electrons
	>500 KeV Protons
G_2	> 20 KeV Electrons
	> 0.3 MeV Protons

Perpendicular to spin axis

Detector G_3	> 40 KeV Electrons
	>500 KeV Protons
G_4	> 80 KeV Electrons
	>110 KeV Electrons
G_5	>200 KeV Protons
	>140 KeV Electrons
	200 KeV - 770 KeV Electrons
G_6	>400 KeV Protons
	> 25 KeV Electrons

Scintillation photomultiplier

S_1	Current mode	> 8 KeV Electrons
	Pulse mode	> 40 KeV Electrons
		> 60 KeV Electrons
	Current mode	> 50 KeV Protons
	Pulse mode	50 - 70 KeV Protons

Proton detector (not sensitive to electrons)

D_1	0.15 - 25 MeV
D_2	0.5 - 4 MeV
D_3	3.4 - 12 MeV
D_4	12 - 30 MeV
$D_{background}$	12.5 - 20 MeV

(5) Soft Particle Spectrometer (Heikkila)

Electrons 10 - 10,000 eV

(6) Ion Mass Spectrometer (Narcisi)

1 - 20 A.M.U.

(7) Cylindrical Electrostatic Probe (Langmuir Probe) (Brace)

Ne and Te

(8) Spherical Electrostatic Analyzer (Spherical Probe) (Sagalyn)

Measures:
- (a) Protons 10 to 6 x 10^6 particles/cm^3
- (b) Thermal ion kinetic temperatures 700 to 4000°K.
- (c) Proton flux and energy 0 to 2 KeV
- (d) Potential of satellite to undisturbed plasma

(9) Beacon (Forsyth)

136.410 MHz, 137.950 MHz, 100 mw beacons

Measures:
- (a) Ionosphere total electron content
- (b) Small-scale variations of electron content
- (c) Ionic inhomogeneities responsible for amplitude and angular scintillations

(10) Cosmic Noise (Hartz)

From AGC of sounder receiver 0.1 to 16 MHz

(11) Antenna Bias

A negative bias may be switched on to both sounder dipole antennas on command; current will be monitored.

Weight Breakdown

Structure	96 lbs.
Experiments	125 lbs.
Telemetry & Command	100 lbs.
Power	150 lbs.
Attitude Sensing & Control	23 lbs.
Cable Harness	38 lbs.
Total	532 lbs.

3.2 Spacecraft and Operations

3.2.1 Electrical Summary

ISIS-I has been operating for 6 - 9 hours per day. Although the spacecraft is presently capable of operating for 10 hours per day in a maximum sun orbit the actual operating time is usually limited by the availability of ground stations. The soft particle spectrometer failed on 26 October, 1969. The trouble appears to be due to a short circuit in a -4 kV power supply rail. According to the experimenter (Dr. Heikkila) occasional abnormal operation of the spectrometer has been observed starting several days after launch.

The on-board tape recorder occasionally fails to start immediately when commanded into playback mode. Nine such incidents occurred between August 7th and October 20th. The latest being on September 30th. Since early September the frequency of the amplitude modulated time code signal, on the dump tapes has occasionally varied by up to +10%. This has been caused by speed changes in the spacecraft tape recorder and confirms the earlier warnings that ionograms produced from dumped tapes may have significant height errors unless the tape recorder in the Data Processing Centre is speed-locked during playback.

The sounder flyback period had decreased to three seconds by mid-August, 1969, but has remained relatively constant since. It is possible that the second and final level of compensation will have to be switched in before the end of 1969. It is too early to say whether the reduction in flyback period is asymptoting to a fixed level or will continue to decrease with time. There appears to be a long time constant mechanism involved in the reduction in flyback period of the sweep frequency oscillator in the satellite. The most likely cause would appear to be due to the gradual evaporation of moisture from dielectric materials in the oscillator circuitry. The resulting changes in dielectric constant and stray capacitance would change the frequencies of the two VHF oscillators and if there was sufficient assymetry there could be a steady upward drift in the sounder starting frequency.

C.A. Franklin.

3.2.2 Mechanical Summary

The computer programme SPINAT 4A which automatically determines the ISIS-I attitude from PCM information on digital magnetic tapes, has been transferred to SATCON for routine operation.

T. Garrett.

3.3 Tape Recorder

The tape recorder continues in regular operation at the rate of about one cycle per 24 hours. Electrically its performance is still very good but the recorder occasionally fails to start immediately when commanded into the playback mode. In a typical occurrence of this sort the tape motion signal rises and then starts to decay again before reaching full output. The recorder starts spontaneously a few minutes later and runs normally thereafter. During the waiting period the current drain of the recorder is higher than normal which is consistent with a stalled condition. So far there has been no evidence of a design weakness in the recorder to account for these occurrences. Lockheed Electronics Company have been asked to carry out starting tests of the tuning-fork oscillator at various temperatures, but these have not yet shown any abnormality. Nine of these incidents have occurred between August 7th and October 20th. The latest was on September 30th.

M.A. Maclean.

3.4 Attitude Sensing and Control

3.4.1 Sensing

Computed results were obtained from Adcole Corporation relating to the effect of the inverted mounting orientations of the solar aspect sensors on solar angle readout; that is, on elevation angle and azimuth angle. It will be recalled that the digital solar aspect sensors were, by mistake, mounted upside down on the spacecraft.

3.4.2 Control

An attitude control manoeuvre was carried out in early September to rotate the top end of the spacecraft (at which end the tape recorder is mounted) away from the sun line. An angular change of about 18° was achieved which advanced the positive spin axis from one side of the orbit plane to the opposite side.

H. Kowalik
R.G. Fujaros.

4. ISIS-B

4.1 Satellite Characteristics

Orbit

1400 Km minimum circular
Inclination - not yet resolved.

Spacecraft Stabilization

Spin stabilized.

Spacecraft Attitude Sensing

Six-probe flux-gate magnetometer	Four probes, range -600 to +600 millioersteds: x-y-z orthogonal set, and s probe along spacecraft x direction. Two probes, range -200 to +200 millioersteds: along spacecraft x and z directions.
Digital solar aspect sensor	Two sensors, each with 180° fan field of view; storage register in electronics.

Spin and Attitude Control System

The system capability is designed to be as follows:

(1) Spin axis in the orbit plane:

- Spin change capability of 0.10 to 0.12 rpm/orbit.
- Attitude control (precession) capability of 2.0 to 2.5° per orbit at a spin rate of 3 rpm.

(2) Spin axis in cartwheel configuration:

- Spin change capability of 0.15 rpm per orbit averaged over one day of operation.
- Precession capability of 0.5° per orbit at spin rate of 3 rpm averaged over one day of operation.

Power System

11,008 n-on-p 10-1/4% (A.M.O.) efficiency solar cells will charge 3 Ni-Cd batteries.
Six main system DC to DC converters.
Operational time after 1 year, minimum of 4 hours per day in 70% sun condition.
Continuous operation: Two consecutive pole-to-pole passes.

Command System

Command

Multiple tone-digital AM AVCO system.
2 receivers operation 148 MHz; 1 redundant.
Decoder capability - 216 commands.

Programmer and Clock

Stored commands for remote turn-on execution.
Capacity - 5 remote turn on from 10 commands
Loading time 5 mins.
Programmer monitoring facility (readout time 3 secs.).
Clock output - serial time code BCD format 60 bps, once per second.
Ground correction capability.
Stability and accuracy 1 sec/week.

Automatic Turn Off

Normal turn off - after 16 mins.
Special turn off - after 8 or 24 mins.
Programmed turn off - after 16 mins.
Backup - after 30 mins. unconditionally.
Spin and attitude control - 3^{+1}_{-0} and 11^{+1}_{-0} hours, selectable by command.

Tape Recorder

Record time - 64 mins.
Playback - 4 times record speed.
Data channels - 4
(a) FM data - sounder output FM bandwidth 1 Hz to 9 KHz.
(b) Ref. frequency 11.52 KHz + AM time code.
(c) Digital data 11,520 bits per sec.
(d) Analog data - VLF output bandwidth 50 - 20,000 Hz.

Telemetry

Transmitter No. 1

Frequency		136.080 MHz: bandwidth 100 KHz
Power		4 watts.
Modulation	FM	Sounder
	PAM/FM	SCO essential housekeeping & clock.
	FM	VLF

Max. range for 10 dB S/N 3500 miles with 19 dB ground antenna gain.

Transmitter No. 2

Frequency	401.75 MHz: bandwidth 500 KHz.
Power	4 watts.
Modulation FM	Sounder
PCM/FM/PM	SCO experimental data & housekeeping.
FM	VLF
AM/PM	SCO satellite clock.

Max. range for 10 dB S/N 3500 miles with 19 dB ground antenna gain.

Transmitter No. 3

Frequency	136.59 MHz: bandwidth 50 KHz.
Power	2 watts.
Modulation PCM/PM	Experimental data and housekeeping.

Tracking Beacon

Frequency	136.410 MHz.
Power	100 mw.
Unmodulated	

Experiments

(1) Swept Frequency Sounder

Power output	400 W at PRF 45/sec.
Antennas	240' and 61.5' tip-to-tip.
Automatic ionogram transmission	

Frequency Range

(a) Normal sweep 0.1 to 10 MHz. Sweep duration 10 secs.
(b) Extended sweep 0.1 to 20 MHz. Sweep duration 20 secs.
(c) Sweep law - linear in all ranges.
(d) Frequency markers:
0.25, 0.5, 0.75, 1.0, 1.25, 1.5, 1.75, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0, 12.0, 14.0, 16.0, 18.0, 20.0 MHz.

(2) Fixed Frequency Sounder

The six frequencies selected for the fixed frequency sounder are:
0.25, 0.48, 1.0, 1.95, and 9.303 MHz.

Sounder Receiver Characteristics

Pre-amp. and filter No. 1 seven bands
(a) 0.1 - 1.0 MHz
(b) 1.0 - 2.0 MHz
(c) 2.0 - 3.0 MHz
(d) 3.0 - 5.0 MHz
(e) 5.0 - 8.0 MHz
(f) 8.0 - 13.0 MHz
(g) 13.0 - 20.0 MHz

Pre-amp. and filter No. 2 wideband 0.1 - 20.0 MHz.
Linear - logarithmic receiver with AGC loop characteristics.
Rise time 60 msecs. Fall time 12 msecs.

(3) VLF Experiment

VLF receiver	0.05 - 39 KHz Monitored AGC voltage
A VLF swept frequency exciter	Range 500 - 0 - 9500 Hz.
Antenna impedance measurement	

Antenna bias. A.D.C. bias can be applied to the antennas by command.

(4) Energetic Particle Detector (I. McDiarmid, J.R. Burrows)

Gieger counters

Parallel to spin axis

G1	>40 KeV electrons >.5 MeV protons
G2	>20 KeV electrons >.3 MeV protons

Perpendicular to spin axis

G3	>40 KeV electrons >.5 MeV protons
G4	>20 Kev electrons >.3 MeV protons

Solid-state silicon junction detectors

G5 Energy thresholds of:	80 and 100 KeV .2 MeV protons
G6 Energy thresholds of:	120 and 200 KeV electrons .4 MeV protons

Proton detectors

D_1, D_2, D_3, and D_B	0.15 - 55 MeV protons

Scintillation photomultiplier

Sc Current mode total energy	> 3 KeV electrons >20 KeV protons
Sp Pulse mode particles at	40 and at 60 KeV electrons 50 KeV protons

(5) Soft Particle Spectrometer (W.J. Heikkila)

Electrons	10 - 10,000 eV.

(6) Ion Mass Spectrometer (J. Hoffman)

Direct measurement of positive ion density mass numbers.
1 - 64 amu.

(7) Cylindrical Electrostatic Probe (Langmuir Probe) (L. Brace, J. Findlay)

Direct measurement of electron density and electron temperatures using two Langmuir probes at opposite ends of the spacecraft.

(8) Ion Temperature (J. Donley, E. Maier)

Direct measurement of electron temperature, ion temperature, ion composition, and charged particle density by retarding potential analyzer.

(9) Beacon (P.A. Forsyth, G.F. Lyon, E.H. Tull)

136.410 MHz, 137.950 MHz, 100 mW beacons.

(10) Cosmic Noise (T. Hartz)

From AGC of sounder receiver 0.1 to 16 MHz. Monitors background radio noise levels due to galactic, solar, and ionospheric sources.

(11) Oxygen Red-Line (6300Å)Photometer (G. Shepherd)

Direct measurement of oxygen red-line emission from aurora and from night, twilight, and air-glow sources.

(12) Auroral Scanner (3914Å/5577Å) (C. Anger)

Direct measurement and mapping of intensity of emissions at two wavelengths.

Weight Breakdown

Structure	100 lbs.
Experiments	147 lbs.
Telemetry & Command	98 lbs.
Power	148 lbs.
ASC System	25 lbs.
Cable Harness	39 lbs.
Total	557 lbs.

4.2 Project Office Report

During the reporting period the spacecraft structure and wiring harness were completed and integration is now underway. At the time of writing, although some detailed work remains to be done in certain cases, the following are essentially completed, and have been integrated in the spacecraft.

Power System
Command System
Telemetry System
Attitude Sensing and Control System

The C.P.M. network was adjusted to accommodate the late availability of a number of sounder system packages, with the result that the Attitude Sensing and Control System has been integrated before the Sounder System.

The late delivery of some experimenters' packages will have a serious impact on the schedule unless a significant improvement can be made on the delivery dates now being projected.

Flight Spacecraft

The spacecraft structure is complete except for the support for the 400 MHz antenna, and the wiring harness is essentially complete, with the exception of a number of cable connectors. As in the case of the prototype spacecraft, the delivery position on some experimenters' packages may well be critical to the schedule for the flight spacecraft.

Solar Cells

The materials problems encountered on the ISIS-I panels appear to have been solved, and delivery of the solar cell panels for ISIS-B is essentially according to schedule. The exposed aluminum surface of these panels was polished in order to obtain a more satisfactory a/e ratio than that on ISIS-I. It is not proposed to conduct measurements on individual panels to establish the extent of the improvement achieved.

Ni-Cd Batteries

Test results from the first lot of ISIS-B Ni-Cd cells have been somewhat disappointing. It is felt that the reason for the unsatisfactory performance of these cells is understood, and steps have been taken to correct the problems giving rise to the high pressure and high voltage conditions experienced.

Magnetometer

Because of misgivings at CRC about the reliability of the existing Dalmo Victor magnetometers, a contract has been let with RCA to design and construct a new magnetometer for ISIS-B. At the time of writing the contract arrangements provide for work to be carried through only to the breadboard stage. It is hoped, however, that it will be possible to extend the contract to provide for construction of two flight-quality units which would be used to replace the existing magnetometer units.

G.H.C. Mackie.

4.3 Spacecraft Operations

4.3.1 Electrical Summary

Failures in pnp and npn "0" pf transistors for the ISIS-B clock and programmer have been diagnosed by CRC's Failure Analysis Facility. The trouble was due to faulty processing producing excessively thin aluminum metallization. This in turn resulted in very high current densities in the metallization in certain high speed circuits in the clock and programmer. The high current density produces electro-migration of aluminum ultimately leading to rupturing and open-circuiting of an interconnection. Motorola agreed with this diagnosis and accordingly it was decided to replace only those "0" pf transistor modules operating at toggling rates greater than 20 KHz. The bulk of the "0" pf transistors installed in ISIS-B clock and programmer boards are being retained.

The ISIS-B schedule continues to cause concern and could slip twenty-two weeks beyond the 21 December,1970 launch date. The trouble is mainly due to late delivery of experiments.

C.A. Franklin.

4.4 Mechanical Design

Structure

The flight model structure was delivered to RCAL from SPAR on 25 July, 1969.

The top heat shield has been modified by stiffening the supporting structure, and the weight of the 400 MHz antenna assembly has been reduced.

A tubular support has been made for the upper cylindrical electrostatic probe to prevent it making contact with the 400 MHz antenna elements.

The modified top end will be attached to the ISIS-I dynamic model structure and subjected to qualification vibration testing at RCAL early in November, 1969.

Solar Cell Panels

One "B" type and "C" type solar panel substrates were sent to RCAL for fit checks with the soft particle spectrometer and oxygen red-line photometer experiments. This task has been completed and the substrates returned to Centralab.

Two flight "A" type solar cell panels were delivered to RCAL from Centralab on 29 September, 1969.

N.A. Harrison.

4.5 Other Satellite Electronics and Experiments

4.5.1 VLF Receiver

The interim design review of the VLF system was held on 17 September, 1969. No major design changes to the VLF receiver have resulted from this review. However, a number of points were raised. Capacitors C1 and C2 in the output feedback amplifier (module A1A6) which were 47 µf at 35 volts in the ISIS-I receiver were changed to 100 µf at 20V for the ISIS-B receiver. This change was incorporated in order to compensate for the lower value of R5 in the ISIS-B receiver. As pointed out in the RCA design analysis of this module, these capacitors are voltage stressed beyond the ISIS rating, which is one-half the voltage specified by the manufacturer. It is possible to eliminate this over-stressed condition by reversing the polarities of the capacitors and returning the bias resistor (R1) to the -9.8V rail instead of the +14.8V rail. However, this "fix" is considered impractical by RCA since it involves modifying the cordwood module printed circuit board. RCA has proposed reverting to the original 47 µf at 35V capacitors and accepting the 0.8 dB degradation in the frequency response at 50 Hz. A closer examination of the work involved in modifying the cordwood P.C. board has been requested.

A discrepancy in the shape of the open loop low frequency response has been noted between the ISIS-B engineering model and the ISIS-I breadboard model. The reason for this difference has not been satisfactorily explained and further investigation is required.

For further details on the status of this unit, refer to the RCA contribution to this progress report.

T. Nishizaki.

4.5.2 Converter 6 (Spin and Attitude Control System)

The interim design review of this unit was held on the 19 June, 1969. No significant design changes have resulted from this review.

For further details on the status of the ISIS-B flight units, refer to the RCA contribution to this progress report.

T. Nishizaki.

4.5.3 DC to DC Power Converters
Main Clock and Programmer
Back-Up Clock and Programmer

There are no further design changes to report on these units. For details on the progress of the flight units, refer to the RCA contribution to this progress report.

T. Nishizaki.

4.5.4 Primary Clock and Programmer

Two-hundred transistors (100 NPN and 100 PNP) were purchased from Motorola to replace "0" pf transistors in modules operating at high toggling rates; i.e., greater than 20 KHz. Due to a large backlog of work at Motorola, the following special screening tests were performed on these devices at CRC:

1. Thermal shock, 10 cycles -75°C to +100°C.
2. Stabilizing bake, 40 hours at 200°C.
3. Power burn-in, 160 hours at 200 mw.
4. h_{fe}, leakage, capacitance measurements.
5. Irradiation cobalt - 60, 3×10^5 rads.
6. Repeat of step 4.
7. Annealing bake, 48 hours at 200°C.
8. Repeat of step 4.
9. Centrifuge (10,000 g) and helium leak test.
10. Final electrical check, h_{fe}, at I_c = 30 mA and V_{ce} = 2V.

Thirty-five of each type were forwarded to RCA Limited, Montreal, in October, 1969.

N.S. Hitchcock.

4.5.5 Tape Recorder

Lockheed are refurbishing the ISIS-I prototype to serve the same function for ISIS-B. To improve the performance of the Time Code channel, the modulation ratio has been increased to 5:1 and the signal output to 2 volts peak-to-peak. Lockheed carried out some tests of a possible alternative magnetic tape which, it was thought, would raise the present permissible upper temperature limit of the recorder (+35°C). The results showed no clear superiority for the new tape during digital drop-out tests when the recorder had been maintained at +40°C and above for many hours. In addition the new tape showed a marked reduction in the output of the analog channel at +45° and had a tendency to stick to the heads at +50°. It has been decided to continue using the original type of tape.

M.A.Maclean.

4.5.6 Magnetometer

Dalmo Victor Flight Units (Serial 1001 and 1002)

During initial thermal acceptance testing at RCA Montreal of the Serial 1001 magnetometer on 28 April, 1969, a malfunction of the X200 channel in magnetometer I occurred at approximately 45°C. This malfunction was characterized by latch-up of the output signal at negative (-0.6V) saturation which was independent of the applied magnetic field. The unit was returned to Radix for repair where the malfunction was traced to an open weld in the signal amplifier module.

At initial bench test after repair and return of the unit to RCA, the X200 channel was observed to operate in an abnormal manner. It was difficult, by orientation of the probe in the earth's magnetic field, to produce a zero field output condition. The output of the channel had a strong tendency to sit in a negative or positive output saturation mode with the former output condition being the predominant one.

The unit was again returned to Radix for repair. It was found during an extensive test period that a 0.22 mfd polar solid tantalum capacitor across the input to the signal amplifier was installed backwards and was under a continuous reverse bias of 3 volts.

The 0.22 mfd capacitor was replaced and the latch-up type behaviour disappeared, but the channel was found to be drastically out of calibration. It was necessary to reduce the value to 0.1 mfd to obtain normal operation. The unit was subsequently thermal tested and all channels found to operate satisfactorily.

Since the initial calibration by Dalmo Victor, the Serial 1001 magnetometer has suffered numerous malfunctions which has resulted in many hours of testing and handling. In addition, the X200 channel signal amplifier has been extensively reworked with the replacement of a number of components. Because of this past history of the magnetometer it was decided to recalibrate the unit.

The Serial 1001 magnetometer was calibrated during the 15th, 16th, and 17th September at the Magnetics Test Facility at GSFC. The magnetometer was calibrated at temperatures of -23°C, +23°C, and +55°C for the probes with corresponding temperatures of -8°C, +23°C, and +40°C respectively, for the electronics unit. Calibration results were somewhat different from the original Dalmo Victor calibration results. However, except for a few minor out-of-tolerance results, the calibration of the magnetometer was satisfactory.

For further details on the recalibration tests and X200 channel malfunction, refer to CRC memorandum 6663-105-3 of August 21, 1969 and September 24, 1969.

At present, the status and past history of both the Serial 1001 and 1002 magnetometers are undergoing review to determine the preferred flight unit.

Proposed RCA ISIS-B Magnetometer

The status of the proposed RCA breadboard magnetometer was reviewed at a meeting held at RCA, Montreal on 2 September. One high sensitivity (+200 mOe full scale) channel has been breadboarded and initial results show satisfactory operation.

The breadboard magnetometer electronics has been temperature tested over the temperature range of -50°C to +70°C at a single near zero applied field. The total variation in output voltage was approximately 0.7%. During this phase, the testing of the magnetometer has been hampered by the lack of a good magnetics facility. However, subsequent inquiries by RCA and CRC were successful in locating a mumetal box, which has proved to be very satisfactory for their tests.

A decision has been made to use the 23.04 KHz output from the clock and programmer for the input frequency to the proposed ISIS-B magnetometer. The frequency will be divided down to produce a drive frequency to the fluxgate sensor of 1.92 KHz. Since the probes were originally designed to operate at a drive frequency of 2 KHz, operation at 1.92 KHz should not be a problem.

A number of comments and recommendations on the proposed magnetometer design have been made and are outlined in CRC memorandum 6663-106-3 of 17 October, 1969.

T. Nishizaki.

4.6 RCA Ltd. Status Report

4.6.1 Management

4.6.1.1 Subcontracts

The remainder of the subcontracted items was received during this period, with the exception of coulometers, which are scheduled for delivery with the batteries and the flight model thermal blankets, which will be delivered and installed shortly before completion of the integration phase.

4.6.1.2 CPM Planning and Schedule

Monthly CPM runs have been made in the last reporting period. An analysis of these runs has shown considerable improvement on the negative position of the clock and programmer units (Units CC, CF) and sounder units.

The optical experiments (Auroral Scanner and Red Line Photometer) have become the most critical units during this reporting period because of late design problems.

4.6.1.3 Spacecraft Integration

Integration of the prototype spacecraft has gone smoothly without any problems. During this reporting period, mechanical fit checks, preliminary antenna match, command system, telemetry system, and the spin and attitude system, have been integrated.

Preliminary integration of the flight model was also started. The wiring harness was completed, and electronic boxes have been installed in preparation for the preliminary match and tuning of the VHF and UHF antenna systems.

4.6.1.4 Reliability and Quality Assurance

a) The Reliability Plan - ISIS "B" was approved during this reporting period after a mutually agreed formula was found to define "satisfactory" and "partially satisfactory" operation of the spacecraft.

A total of seven formal design reviews were held during this period.

Unit	Type of Design Review
ASC Control Unit (JD)	Final
VLF Receiver (EA)	Interim
Command System	Final
Experimenters' Selector Unit (BY)	Interim
Sounder Control Unit (AH)	Final
Auroral Scanner Experiment	Interim
Power System	Final

b) Components

A further screening of 0 pf transistors have been done by CRC and a new type of fast switching transistor has been evaluated and supplied to RCA Limited by CRC. This new type will be used in the flight main clock in the circuits with the highest clock rates.

A problem has been experienced with field effect transistors. New assembly techniques are being tried out using a shorting wire. Two Statrol units have also been installed in the immediate area where FET's are used. There is evidence that this is reducing the number of rejects.

The rejected units have been sent to CRC for analysis.

4.6.2 Project Engineering

Work has continued on preparation and revision of system schematics. A schematic diagram showing the battery switching subsystem is in drafting and a schematic of the sounder system is expected to be ready for drafting by the end of this reporting period.

A drawing which takes the form of a matrix has been prepared which identifies all latching relays in units AC, AD, AF, AM, AQ, BG, BY, BW, CD,CE,DC,DM, DP, EA, JC, JD (83 altogether, and the commands which cause them to be SET and

RESET. This drawing, 1823570, is being used in the preparation of Autocheck steps.

Preliminary flow charts for most of the Autocheck Executive sub-routines have been made. These will be reviewed and coding will begin as soon as programming of the 'ACE' system has been finished.

A first draft of the ISIS-B Environmental Test Plan for the GSFC tests is in preparation.

System problems arising from design reviews or queries raised by experimenters have included the following:

- Reassignment of the redundant commands for modes B1 and D1. These commands are now used to provide ON/OFF control of the sounder mixed mode.

- Addition of a flag signal to indicate extended or normal sounder sweep.

- Re-routing of the redundant turn-on command for the Ion Mass Spectrometer from the Command Decoder to the Command Switching Unit via the IMS so that it may be used to disable the IMS calibrate circuit.

- Routing of the 21.5 volt supply to units AQ, AC, and DC was changed to prevent switching of the power amplifiers when the converter, DC, is operating.

- Modification of the wiring to the under-voltage cutout circuit to prevent loss of this protection when "Extended ASCS Use" is commanded on.

4.6.3 <u>Electrical Equipment Engineering</u>

4.6.3.1 <u>Power System</u>

a) <u>System Design</u>

Two changes have been made in the system design. The first change was required because introduction of the AIT mode had provided an undesirable bypass of the interlock system which prevented change-over of the sounder power amplifiers while power was being applied. The second change was required because provision of the "Extended Use" relay for the attitude control system had introduced an undesirable means of de-activating the under-volatge detector Battery #2. Both changes were implemented by minor wiring modifications.

b) <u>Primary Power System</u>

The solar cell panel contract is proceeding satisfactorily and delivery of flight panels has started. The battery contractor has experienced difficulty with his first production cells in meeting voltage and pressure requirements at low temperatures. No nickel-cadmium cells or coulometers have been delivered as yet. It appears that the problems are due to incorrect process control.

CRC has conducted failure analysis of the coulometer which failed during life tests. The cause of failure was not positively identified but there were indications suggesting a partial short circuit. Continuation of the cycle life test program has resulted in a second coulometer failure with similar symptoms. This is now being investigated.

c) Unit Design

Minor modifications were made to the design of the power control unit to cope with the system changes described above. All power system units have been installed on the prototype spacecraft and are performing satisfactorily. Flight units are either in test or in the late stages of manufacture.

4.6.3.2 Spin and Attitude Control System

a) System Design

No changes have been made to the system design in this period. The System Test Set has been completed and now includes the modifications which will permit the system to be checked with the spacecraft autocheck program.

b) Subcontract Items

The new torquing coil for the flight spacecraft has been manufactured and delivery is expected soon. Solar pippers for the flight spacecraft have been received and have passed acceptance test. The prototype magnetometer electronics unit has passed acceptance tests and is now on the spacecraft.

The malfunction of the flight magnetometer electronics unit was due to inverted connection of a polarized capacitor. It has been repaired and is now receiving its acceptance test.

c) Unit Design

Design reviews have been held on Converter 6 (JC) and the ACS Control Unit (JD), resulting in a number of minor modifications. Most of the changes were to improve stress level in some components or improve noise immunity. In unit JD the short term stability of the level detector was improved by adding a pre-regulator to the reference signal source and an increased drive signal was provided for the torquing coil switching transistors to improve the design margin.

4.6.3.3 Telemetry System

a) System Design

Two minor changes to the telemetry system design have been under consideration during this reporting period. One change involves the addition of a simple one-bit "command totalizer" flag circuit which can be telemetered via both PCM and PAM telemetry, thus providing command confirmation independently of the main clock and programmer. The other change involves additional circuitry to enhance the reliability of sounder video transmission via the 400 MHz telemetry system. It is expected that both changes will be implemented in the Experimenter Selector Unit (code BY), though no final decision has yet been made. There have been a number of minor changes in the design of various flag circuits to improve reliability, and some new flags have been added.

b) Subcontract Items

Tape recorder Serial No. 3 was successfully installed and checked out in the prototype ISIS-B spacecraft. Delivery of tape recorder Serial No. 2 has been delayed owing to magnetic tape evaluation tests. The refurbished unit is now expected to become available in early November 1969. After this unit has been tested at RCA Limited, tape reocrder Serial No. 3 will be returned to the vendor for refurbishing.

c) RF Unit Design and Testing

During this reporting period the second 136 MHz PM transmitter (code BB) successfully passed unit acceptance tests and is now available for integration. Thus all four 136 MHz telemetry transmitters required for the ISIS-B program have been completed. Completion of the two 400 MHz telemetry transmitters is being delayed by tests to evaluate transmitter "breakdown" phenomena. This evaluation is being conducted in a new Tenney thermal vacuum chamber using a test circuit which is identical to the last two stages of the 400 MHz transmitter, including the use of flight-quality transistors. The Tenney chamber was received at RCA Limited and became operational on October 16, 1969. The tests are proceeding satisfactorily and should be completed early in November.

d) Subcarrier Oscillators

Design work is continuing on the 30 KHz and 93 KHz subcarrier oscillators for the ISIS-B spacecraft. The 30 KHz oscillator is in the final design stages, and a breadboard model has been constructed and is currently undergoing tests over the environmental temperature range. The design of this unit is expected to be complete by November 10, 1969. A 93 KHz oscillator has been designed and tested, but has shown some linearity and frequency drift problems. It is expected that these problems can be overcome by using a faster operational amplifier in the integration circuit, and work is underway on this at the present time. The design of the 93 KHz unit should be complete by November 30, 1969.

e) Experiment Selector Unit

The engineering model of the Experiment Selector Unit (code BY) was completed and installed in the prototype spacecraft in lieu of the prototype Selector Unit. The design of the prototype and flight models is being revised as a result of decisions taken during an internal design review meeting on August 20, 1979 and an interim design review meeting on September 26, 1969. The redesign is expected to be complete by November 17, 1969.

f) Commutators and Encoders

One prototype PCM Encoder (code BP) is fully qualified and integrated on the prototype spacecraft. The other prototype unit is completed except for acceptance tests. This is expected to be completed and available for integration by November 7, 1969. Both flight model PCM Encoders are in the final stages of manufacturing. One prototype Analog Subcommutator (code BS) is completely qualified and integrated on the prototype spacecraft. A second unit, which is fully operational but unqualified, is also integrated on the prototype spacecraft. A third unit is in final stages of manufacturing. A fourth unit was damaged during assembly and is held for delivery of new components. Components have also been ordered to enable a fifth unit to be built in case the unqualified prototype unit cannot pass acceptance tests. Both prototype Digital Subcommutators (code BU) have been qualified and integrated on the prototype spacecraft. One flight model Digital Subcommutator is in final stages of test and the other is in final stages of manufacturing. The engineering model Essential Housekeeping Commutator (code BR) is currently installed in the prototype spacecraft in lieu of the prototype unit, which was damaged during assembly and is now being repaired. The flight model Essential Housekeeping Commutator is currently awaiting assembly. The problems encountered during assembly of the Analog Subcommutators and the Essential Housekeeping Commutator have mostly been due to failure (increased leakage) of the field effect transistors used in the analog signal switching circuits. This problem is currently under intensive investigation.

g) Antennas

All prototype units of the VHF telemetry and command antenna system have been integrated on the ISIS-B prototype spacecraft. All flight units are qualified and available for integration except for the Telemetry and Command Antenna Unit (code BD) and the Telemetry and Command Duplexer (code BE). The engineering model of the 400 MHz Antenna Unit (code BZ) successfully passed vibration tests and is currently being used in the prototype spacecraft in lieu of the prototype unit. The prototype and flight units are in the final stages of manufacturing. Both the prototype and flight models of the 400 MHz RF Harness (code BJ) are qualified and available for integration. The prototype and flight model Beacon RF Harness (code BN) are also qualified and available for integration. The prototype Beacon Antenna Unit (code BX) is in final stages of manufacturing.

4.6.3.4 Command System

a) System Design

No significant changes have been made in the design of the ISIS-B command system during this reporting period. A design review of the command system was held on September 18, 1969, at which time it was noted that some command loads on the Command Decoder outputs can exceed specification limits of 100 mA under worst case combinations of component tolerances, battery voltages, and temperatures. An investigation is currently underway to determine the implication of this problem and to establish whether excessive loads are potentially hazardous for the Command Decoder unit.

b) Unit Design and Testing

Both prototype Command Receivers (code CA) and the prototype Command Decoder (code CB) are fully qualified and integrated on the ISIS-B spacecraft. Both flight model Command Receivers and the flight model Command Decoder are also qualified and available for integration. The prototype Clock and Programmer (code CC) has been completely assembled and is in the final test stage. The flight model Clock and Programmer is in the manufacturing stage with approximately 50% of the modules built and tested. The prototype Back-up Clock (code CF) has also been completely assembled and is in the final test

The flight model Back-up Clock is in the preliminary manufacturing stage. The prototype A.T.O. Unit (code CD) is fully qualified and integrated in the prototype spacecraft. The flight model A.T.O. unit is in the final stage of manufacturing. Both the prototype and flight model Switching Units (code CE) are fully qualified, and the prototype unit has been integrated in the prototype spacecraft.

4.6.3.5 Sounder System

a) System Design

The Sounder System design has been modified to accommodate the addition of a range marker pulse in the video format and the incorporation of new circuitry to provide a more linear A.G.C. characteristic in the receiving system. The latter change will affect the flight system only. It has been decided that both sounder transmitters in the ISIS-B flight spacecraft are to be 400-watt units and that the two 100-watt transmitters are to serve as back-up units.

b) Unit Design and Testing

For reliability purposes it was decided to replace the tantalum capacitors in the prototype 400-watt and 100-watt Power Amplifier units (code AA and AB respectively). The prototype 400-watt unit has been requalified and is available for sounder subsystem tests. The prototype 100-watt unit is in the final stages of retesting. The flight model 400-watt and 100-watt Power Amplifier units are in the final stages of manufacturing. The prototype Antenna Interface unit (code AC) is undergoing qualification tests and the flight model of this unit is in the intermediate stage of manufacturing. The prototype models of the Receiver Input unit (code AD) and the Sounder Receiver unit (code AE) are fully qualified and available for subsystem tests. The flight models of these units are in the final stages of manufacturing, but some modifications will be required in both of these units to accommodate the new A.G.C. circuitry referred to above. The prototype R.F. Generator unit (code AF) is in final test and the flight model is in the final stages of manufacturing. The prototype Frequency Calibrator (code AG), which had been fully qualified previously, is undergoing modifications to accommodate the faster sweep rate used in the ISIS-B sounder system. The flight model of this unit is in the intermediate stages of manufacturing. The numerous modifications required to accommodate video format changes have led to considerable delays in the production of the Sounder Control unit (code AH). At the present time the prototype unit is in the final stages of manufacturing and the flight unit is in the intermediate stages. The prototype Amplitude Calibrator unit (code AM) is fully qualified and available for integration. The flight unit is in the final stages of manufacturing. Both the prototype and the flight models of the A.I.T. Control unit (code AQ) are in the initial stages of manufacturing.

4.6.3.6 VLF System

a) System Design

No significant changes have been made in the design of the VLF system during this reporting period.

b) Unit Design and Testing

The design of the VLF Exciter Driver unit (code AP) has been modified to delete the automatic cycling feature in the output attenuator. Medium and low output levels will be available on command. The interface problem between the VLF Exciter and the impedance measuring cirucits has been successfully resolved. A recessed cover has been incorporated in the Exciter unit to facilitate unit assembly and potting. The engineering model of the VLF Exciter Driver unit is available for installation on the ISIS-B prototype spacecraft in lieu of the prototype unit, which is in the final stages of manufacturing. The flight unit is in the initial stage of manufacture. The prototype VLF Receiver unit (code EA) is in the final stage of manufacturing. The engineering model of this unit will be used for prorotype spacecraft integration until the prototype unit is qualified. The flight model of the VLF Receiver unit is in the initial stage of manufacturing.

4.6.3.7 Optical Experiments

a) Auroral Scanning Photometer

The engineering model of this experiment is undergoing final environmental tests at A.P.L. All drawings have been released to Manufacturing and procurement of components, printed circuit boards, and metal work for the prototype and flight models has commenced. The design analysis of the electronics section has been updated and released, and an interim design review was held October 24, 1969.

b) Oxygen Red Line Photometer

Environmental tests of the engineering model of this experiment have been successfully completed. All drawings have been released to Manufacturing and procurement of components, printed circuit boards, and metal work for the prototype and flight models has commenced. Work is also underway on the preparation of test specifications and fixtures. A meeting was held on August 29, 1969, to review the engineering model test results.

4.6.3.8 Ground Support Equipment

a) Main GSE

All modifications required in the main GSE have been incorporated and all racks have been tested except for the Transmitter Rack (code FN), one Battery Charge Console (code FJ) and the Spin and Attitude Control Console (code FV). The Divcon equipment has been delivered (except for monitors)but has not as yet been connected to the GSE computer owing to problems encountered in the computer itself. All additional peripheral equipment required for the GSE computer, including disk, extra core memory, A/D converter, multiplexer, and additional tape transport have been received and installed. Some problems have been encountered in operating the computer tape peripherals since the extra core memory was installed. This is believed to be due to deficiencies in the tape transport control unit. The problem is currently being investigated by representatives of the Digital Equipment Corporation. Completion of the main GSE is being held up by this problem.

b) Auxiliary GSE

The auxiliary GSE racks have been completed and checked out, and are currently being used during integration of the prototype ISIS-B spacecraft until the main GSE becomes available.

c) Software

Most of the programming effort to date has been expended on updating the ISIS-A ACE program, designing a new BASYS system adequate for the additional computer peripherals, and designing a new ACE program suitable for ISIS-B spacecraft integration and checkout activities. The updated ISIS-A ACE program, which is completely debugged and available, will be used temporarily until the new ACE program becomes available. The new BASYS system is complete and available, and the new ACE program is expected to be available by December 26, 1969. Some preliminary analysis has been done on the ISIS-B Autocheck system requirements, and programming is expected to begin on this system by December 1st, 1969.

4.6.4 Mechanical Equipment Engineering

4.6.4.1 Prototype Spacecraft Integration

Unit integration and fit checks continue to be performed as the units become available.

Problems were experienced with the Soft Particle Spectrometer Detector and Encoder boxes with respect to connector accessibility, however, these problems have been solved satisfactorily by modifying the Encoder Detector units and dressing of the spacecraft harness.

4.6.4.2 Flight Spacecraft Integration

The flight spacecraft structure was received at RCA Limited on 26 July, 1969.

The structure has been prepared, by way of rib and equatorial panel rib drilling, for integration functions to proceed.

The wiring harness has been installed and fit checking of available units has started in preparation for antenna matching.

4.6.4.3 Mechanical System

The current weight estimate for the spacecraft is 557 pounds made up of 307 pounds weighed, 158 pounds estimated, and 92 pounds based upon measured unit weights combined with estimated encapsulant weights. The current inertia ratio of the spacecraft is 1.053.

A qualification type vibration test was carried out on the engineering model auxiliary heatshield assembly with the engineering model units of the 400 MHz and beacon antennas. It was necessary to strengthen the auxiliary heat shield and the monopoles of the 400 MHz antenna, in order to complete the vibration schedule. The report of this test, RCA drawing #2512817, has been issued. The prototype and flight auxiliary heat shields are being modified and a vibration schedule to re-check the modifications will be performed early in the next reporting period.

The upper cylindrical electrostatic probe also failed during the original vibration schedule. A modification to hold the probe erect has been completed and this will be evaluated during the next vibration schedule.

A thermal vacuum soak on both flight and prototype honeycomb panels was performed at CARDE during 2nd September to 5th September, 1969, to pre-condition them to reduce outgassing.

J. McNally.

5. SATELLITE CONTROL

5.1 General

There continue to be many deletions in the Alouette/ISIS schedules because of conflicts at the STADAN and TROMSO stations.

5.2 Alouette I

Alouette I operated in the sounder and/or VLF mode for about 1-1/4 hours per day during this period. There has been no other change in the operation of Alouette I.

5.3 Alouette II

Alouette II operated between 3-1/4 and 5-1/5 hours per day during this reporting period. The 100 watt power amplifier continues to be used in the sounder system. The spin rate is now 1.86 rpm. There have been no other changes in the operation or status of Alouette II during this period.

5.4 ISIS-I

ISIS-I operated between 6 and 9 hours per day during this reporting period, one hour of which was stored in the on-board tape recorder. The power system is presently capable of operating the spacecraft up to a maximum of about 10 hours per day, but data acquisition network conflicts (often totalling 2-1/2 hours per day) have decreased the actual operating time from that schedule.

Since the beginning of August, there have been many occurrences of a delay (up to 9 minutes) of the start of sustained tape movement in the on-board recorder during playback. In many of these occurrences a limited amount of tape movement took place immediately after turn-on, which indicates that the problem is probably not mechanical. There has been no observed occurrences of a similar problem during recording phases. There has been no noticeable decrease in the quality of the recorded data.

The spacecraft spin axis was moved about 18 degrees during the early part of September to move the top of the spacecraft away from the sun. The spin and attitude control system continues to operate as expected.

After one level of compensation was switched in during May, the fixed frequency sounding period decreased to about 3 seconds by mid-August and has remained relatively constant since. The ISIS-I orbit entered 100% sun at the beginning of August.

The spacecraft clock has been held to within 0.6 seconds of G.M.T., by periodic (about every six weeks) corrections of ± 1 second.

The IMS high-voltage monitor channel continues to show that this experiment is not operational.

J.D.R. Boulding.

6. DATA PROCESSING

6.1 Production

The production activities of the Data Processing Centre together with related information are summarized as follows:

6.1.1 ISIS-I

a) Normal Data

No routine processing of any tapes was carried out from 19 June to 24 July due to the new requirements for film presentation of the satellite status as derived by the computer from PCM data.

10,500 ft. of film has been processed for the World Data Centre.

7,200 ft. of film has been processed for special requests.

Current backlog is 1842 rolls of magnetic tape.

b) On-Board Tape Recorder Data

Since speed variations in the playback mode have been observed in the on-board tape recorder, it will be necessary to speedlock the Data Processing Centre's playback tape recorder to the data stream, either to the clock at 46080 Hz or to the PCM bit rate to ensure accurate height markers. The speedlock unit is under development. Thus, the ionograms delivered to the World Data Bank for the period 29 January, 1969 to 30 April, 1969 must be regarded as tentative data only. Some special requests have been processed since April with the same reservation applied to the resultant data.

6.1.2 Alouette I

2,000 ft. of film has been produced for the World Data Centre. Current backlog is 462 rolls of magnetic tape. Processing of Alouette I tapes from the old position has been essentially closed down due to the inability to produce ionograms to present-day standards.

6.1.3 Alouette II

8,300 ft. of film produced for World Data Centre. 7,700 ft. of film produced for special requests, tests, and re-runs.

Current backlog is 3,277 rolls of magnetic tape. The inability of this position, in spite of considerable effort to achieve productive operation, has been due in part to extensive modifications to meet new high standards of accuracy imposed since the new engineering ionogram production unit came into operation.

6.1.4 Compacted Magnetic Tapes

150 magnetic tapes have been compacted with Brace Probe data.

6.2 Development

a) The means for "Satellite Status" presentation on photographic film has become operational on the engineering model of the improved Ionogram Production unit (ionogram processor). The unit produces acceptable ionograms (mainly ISIS-I) from telemetry tapes played back at four times the record speed.

b) Three Ionogram Production units, presently under construction, will not be operational until January 1970 instead of late November 1969 as originally planned. Most of the delays can be attributed to:

i) the loss of an experienced technician;

ii) the need to carry out a number of special projects in the Data Processing Centre (see following paragraphs);

iii) assistance in repair of equipment in the Data Processing Centre;

iv) the drafting of Bureau of Classification Revision forms.

c) A special calibration test tape has been generated and copies will be available for distribution. The purpose of this tape is to provide a synthetic video signal on which synthesized crystal controlled range markers have been superimposed, for checking ionogram production equipment and/or tape recorder idiosyncrasies.

d) A system using the satellite PCM clock frequency as a reference that is compatible with the speedlock requirements of commercial tape recorders is under development. This will permit the playback tape machine to have its speed locked to that of the satellite tape recorder, thereby minimizing errors in the production of ionograms from the ISIS "dump" tapes. (Recorded tapes played back to earth from the on-board satellite tape recorder via the 400 MHz telemetry link.)

e) A method of presenting the sounder receiver AGC (cosmic noise) level superimposed on the ionogram is under consideration. The presence of the AGC level will aid in the interpretation of ionograms since the system gain will be obtainable directly and will be in time synchronization with the ionogram data. The basic technique has been established. Sample ionograms with and without the receiver AGC will be prepared shortly for demonstration purposes.

D.P. Henderson.

7. TELEMETRY STATIONS

7.1 Ottawa

The Ottawa Ground Telemetry Station continues to provide routine operation with Alouette I, Alouette II, and ISIS-I.

The command polarization switching has not been installed due to the long delivery time of the transfer relays, thus occasional command difficulties continue to disrupt loading of the programme store on ISIS-I. The relays are to be installed during the next reporting period.

The Kennedy 60 foot parabolic dish antenna is operating in the programmed mode. The monopulse feed is now operating as is the ITT monopulse receiver. Problems in the electronics portion of the antenna drive system have prevented closure of the servo loop. The problems are due to the original electrical design of the system and to the deterioration of its electronic components.

The mechanical components of the Kennedy dish have been inspected by R.F. System Inc. who report the dish to be in sufficiently good mechanical condition to expect a further ten years of useful structural life. This expected life of the mechanics would warrant resurfacing of the reflective mesh for use at frequencies up to 2.2 GHz if required, and the modernization of the control system to provide a more accurate drive with monopulse tracking.

7.2 Resolute Bay

Resolute Bay continues to receive telemetry data from Alouettes I and II, and ISIS-I.

The station was visited in late August and put into good operating order.

Occasional command problems continue to be encountered with ISIS-I which are caused by the lower radiated power at Resolute relative to Ottawa, and by the lack of polarization switching.

W.S. Campbell.

8. QUALITY ASSURANCE

As ISIS-B electronics unit production at RCA Ltd. reached a peak in this reporting period, malfunctions during initial bench testing also hit a peak. To date, the number of malfunctions reported is 162. Of these malfunctions, the primary area of concern is semiconductor device failure or degradation. Motorola SS1018 & SS1019 "Zero pf" transistors and Fairchild Low Power DTμL integrated circuit degradations were previously reported in June 1969. These devices were analysed by the CRC Failure Diagnostics Group and reported in the following documents:

(1) "Quality Assessment Report on Motorola 'Zero pf' Transistors" by D.V. Sulway, 3 July, 1969.

(2) "Failure Analysis Report on Fairchild Type LPDμL 9040, 9041, and 9042 Integrated Circuits", by D.V. Sulway, 4 June, 1969.

Decisions were taken at project management level for replacing some devices and retesting and selecting existing stock. These decisions are presented elsewhere in the 20th Tri-Annual Report.

The most recent serious device failures to occur were on Union Carbide field-effect transistors (FET) UC 451 and FD 1096. There were two failure mechanisms:

(1) loose particles inside the transistor can cause intermittent operation, but in one example a particle had caused an internal short;

(2) electrical breakdown or serious degradation resulting from external electrical transients or possibly static.

Two parallel courses of action are underway. The failed or degraded devices are being investigated at CRC to determine the failure mechanisms, while RCA Ltd. has taken steps to eliminate two possible causes of external electrical stress by neutralizing ground line transient effects and by installing localised bench-mounted static-reducing equipment.

Investigation is going on at CRC and DREO to determine the causes of failure of two coulometers during life testing at RCA Ltd. Coulometer #110 failed after 870 cycles, while coulometer #121 failed after 500 cycles. Each cycle is of 5 hours' duration.

A review of ISIS-B malfunction reporting procedures highlighted three areas that could be improved:

(1) the interface between RCA Ltd. Quality Assurance Engineering when part failure analysis action was required;

(2) the follow-up action of Quality Assurance Engineering when a malfunction report was first initiated by Design Engineering, and

(3) summarizing on the closed malfunction report all stress analyses resulting from correcting malfunctions.

An improved malfunction reporting procedure was implemented.

J.E. Tennuci.

9. PROJECT SUPPORT

9.1 ISIS Planning and Scheduling

9.1.1 RCA Ltd. Status

Integration of the power, command, telemetry, and ASC systems has been completed on the prototype spacecraft.

It is expected that the critical units of the sounder system will be available for integration by mid-December.

Maximum effort is being applied to the assembly of all outstanding units for the flight spacecraft, and a completion date of mid-March for all units, including the electronic assemblies for the optical experiments, is planned.

Monthly CPM runs have been made during the reporting period with the optical experiments and redesign of the SOC's appearing as the most critical.

9.1.2 CRC Status

A second PDP-8 computer and peripherals, a 16 mm microfilm system (for recording DIVCON displayed data), a frequency synthesizer, and a six word selector have been delivered to RCA, and the ISIS ground support facility is now complete. The GSE is now capable of satisfying the requirements of spacecraft integration and preparation of autocheck software simultaneously.

Investigation by the CRC Failure Analysis Group of Motorolo '0' pf transistors has revealed deficiencies in the metallization and wire bonding techniques used in their fabrication. New Motorola devices have been purchased and supplied to RCA Ltd. after undergoing burn-in and testing at CRC.

J.A. Moffatt.

10. SUPPORTING RESEARCH AND DEVELOPMENT

10.1 Computer-Aided Design

10.1.1 Network Analysis Programmes

ECAP has been used successfully from the remote (PDP-9) terminal. The user creates a description of the network in the ECAP input language, using the facilities of the PDP-9 editor, and this is stored on magnetic tape. It is then transmitted to the 3200 which performs the analysis and returns the results for typing on the PDP-9's teletype. The response time for small circuits is a matter of a few seconds. It is already apparent that a major drawback of this system is the time taken to type the results. Nonetheless, it is proposed to implement a similar system for remote entry of ECAP jobs to the SIGMA 7 time-sharing system to serve until the graphical method is fully implemented.

10.1.2 Computer Graphics

The major portion of the schematic-drawing programme has been completed. The user can create schematics of two-terminal R, L, and C components, together with independent voltage and current sources. Still to be added are facilities to allow the use of the ground symbol, to create dependent current sources, and to allow the deletion of components and connections. The programme lends itself to generalizations in a number of areas and more sophisticated capabilities will be added from time to time.

A programme for labelling the components and electrical nodes has been written. The user can create labels for the components consisting of a 3-character name and a 6-character numerical value and can position these at any position on the display to give a clear and unambiguous schematic. Electrical nodes can be assigned a 3-character name. The names and values are stored in the data structure and so are available both for the display of the schematic and for the abstracting of data for circuit analysis. Advantage is taken of the interactive nature of the system to prevent the user from assigning identical names to more than one component or node, and from entering values having incorrect syntax.

Programmes for allowing the user to specify the components and nodes for which numerical results are required and for abstracting the data required by the analysis programme are now being written. It is hoped that the next reporting period will show a demonstration of circuit analysis with interactive graphical input and either teletype output or a rudimentary graphical output of results.

10.1.3 PDP-9 Computer System

Memory size limitations have been severely felt during this period. The schematic-drawing programme is now large enough that it cannot be assembled on this machine without overflowing the assembler's symbol table. It is also impossible to load the drawing programme and the labelling programme simultaneously. An additional 8k words of core memory are presently being installed to remedy these deficiencies.

The magnetic drum is now being used for the storage of system programmes by means of a simple programme which can dump and retrieve complete core-images. It is now possible to load any of the standard utility programmes (editor, assembler, etc.) in a fraction of a second which has greatly speeded programme development. A complete drum-image can be dumped and retrieved from DEC tape to allow a quick changeover from one set of programmes to another (about 20 seconds).

A simple overlay system is currently being developed which will use the drum to give a very fast replacement or arbitrary-sized blocks of memory. This will be used to enable very large applications systems to be built up, offering a wide variety of options to the user and with very fast response.

10.1.4 Automated Semiconductor Measurements

The design of the interface between the PDP-9 and the measuring equipment is complete, the components are nearly all in hand, and construction is about to start.

M.A. Maclean H.M. Grant
R.G. Fujaros R.E. Warburton
H.G. Bown J.B. Kenney

10.2 Low Conversion Loss Mixers

A simplified theory of ring diode mixer conversion loss when the input is terminated in a low-pass filter and the output is series- or parallel-tuned was completed during this period. To test the theory, 3-, 4-, and 5-pole low-pass filters with corners at about 250 KHz were designed, constructed, and evaluated with special attention given to the impedance responses of the filters. The broadband mixer conversion loss performance was measured using the above filters. The dependence of the conversion loss on number of poles, frequency of input, and ratio of load resistance to source impedance was investigated. It was found that a broadband (50 KHz - 300 KHz) mixer conversion loss of 1-2 db could be readily attained although the optimum load resistance agreed only approximately with that predicted by the theory. The predicted value of conversion loss was zero to 0.7 db depending upon the impedance characteristics of the low-pass filters.

Since the frequency range of the ionospheric sounder extends to about 20 MHz, it was decided to extend the frequency range of the above investigation to 20 MHz. It was found that in order to obtain circuits with reasonable Q's at both input and output, a nominal impedance level of about 400Ω was required. However, the impedance level was found to be prohibitively high when attempting to design low-pass wideband (up to 100 MHz) transformers. Various configurations were investigated in an attempt to overcome this problem. The configuration decided upon consisted of a signal feed through the centre tap of the LO transformer secondary with a parallel-tuned balanced-to-unbalanced matching network IF output thereby eliminating all transformers in the signal path.

The resulting mixer system when operated from a resistive source, and using a local oscillator transformer with a low inter-winding capacity, gave a 1.8 db conversion loss for diode rings using IN3600 diffused diodes. Using hot carrier diodes such as the HPA2396 and HP1002 the conversion loss was approximately 3 db. It is believed that these low conversion losses are partly due to some parametric amplification taking place in the diodes. This conclusion tends to be supported by measurements on a diode ring mixer using abrupt-junction type VAT73ET Varian diodes. With these diodes an actual conversion gain was observed for input frequencies up to 1 MHz - corresponding to a local oscillator frequency of 20 MHz (19 MHz IF).

In all cases, it was observed that if the local oscillator drive level was increased beyond about 2 mA peak per diode, the conversion loss began to increase. The cause of this effect has not been determined but may be related to changes in parametric amplification.

Low-pass filters (3-, 4-, and 5-pole Butterworth) were designed and constructed with corner frequencies at 25 MHz. It was necessary to modify the designs in order to accommodate the self-resonances of the inductors used. It was decided to include the filter as an integral part of the mixer system when it was found that the capacitances of the BNC coaxial cable connectors greatly affected the impedance of the filters. The resulting mixer system is now being evaluated.

A report on the effect of frequency dependent terminations on mixer conversion loss is underway.

R.J.P. Douville.

10.3 The Soft Electron Spectrometer (SES) Rocket Experiment

One spectrometer remains to be flown on NRC rocket ABD-VB-24 at the Churchill Research Range. The payload is to be reactivated for launch by 1 December, 1969 and to remain on standby for type A aurora until March 31, 1970. Two SES instruments, a flight model and flight spare, which have recently been modified and recalibrated, will be available for this flight.

In June the CRC Model Shop built and assembled a new set of curved deflection plates for the soft electron energy selector. This new deflection plate assembly, designed by the project scientist, Dr. D.J. McEwen, had a greatly reduced amount of insulating material exposed at the top and bottom of the plates, on which an electric charge could accumulate. Nylon insulating material was used as suitable Kel-F stock was not available. Subsequent vacuum system tests indicated that this new deflection plate assembly would deflect electrons with energy as low as 25 ev compared to 80 ev in the original curved plate system. The test results supported the view that to reliably detect electrons with energies of a few 10's of electron volts, in the presence of electrons with a wide energy spectrum, care must be taken to ensure that the arrival path of the electrons is electrostatically shielded from insulating materials capable of developing and maintaining a surface or subsurface electric charge when bombarded by soft electrons.

In August two new deflection plate assemblies were built similar to the new design. The flight assemblies necessarily required some additional nylon material at either end of the deflection plate cavity for the support of grid structures and metal apertures. Preliminary tests on these units have indicated that electrons, with energy as low as 50 ev., can be detected consistently. The deflection factor for electrons with energy $\geq$100 ev is quite stable.

A modified electron source was constructed which illuminates the entire outer aperture of the detector with mono-energetic soft electrons. Deflection factor measurements, made using the new source, were consistent with those obtained with the original one. Comparative results strongly indicated that unknown characteristics of the electron source had not been a primary factor in the variations observed in the apparent deflection factor or the low energy cutoff point of the detectors.

No definite conclusions have been reached on the cause of high voltage breakdown in the last flight. To minimize the possibility of further trouble, the electronic box from VB-24 has been returned to CRC for extensive thermal vacuum tests. A hard thermal vacuum soak procedure is being used to eliminate as many potentially high voltage breakdown problem areas as possible.

Calibration data, drawings, and specifications for five spectrometers have been consolidated and sent to the project scientist who is now with the University of Saskatchewan.

G.T. Bird.

11. ISIS TRAVEL

Jul.	6 - 9	J.E. Tennuci	Westmount
	3 - 4	G.H.C. Mackie	"

Jul.	4	A.B. Shearer	Westmount
	8	J.B. Bennett	"
	3	F. Daniels	"
	4	H.R. Raine	"
	3 - 4	J.S. Matsushita	"
	3	J.A. Moffatt	"
	3	J.E. Tennuci	"
	9 - 10	A.B. Shearer	"
	7	S. Ayre	"
	10	R. Barrington	"
	10	N.A. Harrison	"
	9 - 10	T. Hartz	"
	10	H.R. Raine	"
	10	R.S. Gruno	"
	9 - 10	C.D. Florida	"
	9 - 10	F. Daniels	"
	9 - 10	J.S. Matsushita	"
	9 - 11	J. Else	"
	9 - 10	J.A. Moffatt	"
	9 - 12	L. Petrie	"
	9 - 10	A.R. Molozzi	"
	9 - 10	G.H.C. Mackie	"
	14 - 15	R.S. Gruno	"
	16 - 17	R.S. Gruno	Washington
	9 - 10	T. Nishizaki	Westmount
	17	F. Daniels	"
	17	J.E. Tennuci	"
	16 - 17	G.L. Nelms	Washington
	16 - 17	J. Mar	"
	17	J.A. Moffatt	Westmount
	16 - 17	J. Chapman	Washington
	23	T. Nishizaki	"
	23	F. Daniels	Westmount
	23	J.E. Tennuci	"
	29	N.A. Harrison	"
	29 - 31	M.A. Maclean	Plainsfield, N.J.
	16 - 17	C.D. Florida	Washington
	30 - 1 Aug.	J.L. Lackner	New York
	16 - 17	I. Paghis	Washington
Aug.	1	J.S. Matsushita	Westmount
	7	J.E. Tennuci	"
	5 - 11	T. Nishizaki	Anaheim, Calif.
	14	J.E. Tennuci	Westmount
	14	J.A. Moffatt	"
	19 - 10 Sept.	W. Campbell	Resolute Bay
	19 - 10 Sept.	J. Sawtell	" "
	20	N.A. Harrison	Westmount
	20	J.A. Moffatt	"
	22	J.E. Tennuci	"
	7 - 21	S. Ayre	"
	20	F. Daniels	"
	21	J. Else	"
	21	G.H.C. Mackie	"
	27	J.E. Tennuci	"

Aug.	28	J.S. Matsushita	Westmount
	29	N.A. Harrison	"
	27 - 28	J.A. Moffatt	"
	28 - 29	G.H.C. Mackie	"
	29	F. Daniels	"
	28 - 29	J. Else	"
	29	T. Nishizaki	"
	22 - 14 Sept.	C.D. Florida	Tokyo, Japan
Sept.	2	G.H.C. Mackie	Westmount
	3	J.A. Moffatt	"
	2	H.R. Raine	"
	4	J.E. Tennuci	"
	2 - 3	J. Else	"
	11	J.E. Tennuci	"
	8 - 10	R.J. Bibby	Washington
	11	J.A. Moffatt	Westmount
	12	R.F. Hahn	"
	16 - 17	G.H.C. Mackie	"
	16	J.A. Moffatt	"
	2	T. Nishizaki	"
	16 - 17	J.E. Tennuci	"
	18	J.D.R. Boulding	"
	18	H.R. Raine	"
	18	N.S. Hitchcock	"
	15 - 17	T. Nishizaki	Washington
	17 - 18	J.S. Matsushita	Westmount
	14 - 17	R.J. Bibby	Washington
	8 - 10	J.D.R. Boulding	Washington
	18	J. Bennett	Westmount
	17	W. Mather	"
	18	F. Daniels	"
	29	N.A. Harrison	"
	25 - 26	J.E.Tennuci	"
	26	N.S. Hitchcock	"
	26	J.S. Matsushita	"
	26	J.E. Tennuci	"
	26	G.H.C. Mackie	"
	8 - 10	C.A. Franklin	Washington
	26	F. Daniels	Westmount
	29 - 1 Oct.	R.F. Hahn	"
	8 - 10	J. Mar	Washington
	8 - 10	E.S. Warren	Washington
Oct.	8 - 10	J. Else	Westmount
	10	F. Daniels	"
	10	R.F. Hahn	"
	10	G.H.C. Mackie	"
	8 - 9	J.A. Moffatt	"
	8 - 9	J.E. Tennuci	Waterloo
	16	J. Else	Westmount
	16	J.A. Moffatt	Westmount
	22	R.F. Hahn	"
	23	J.A. Moffatt	"
	23 - 25	J. Else	"
	24 - 25	G.H.C. Mackie	"

Oct.	21 - 22	F. Daniels	Westmount
	10	C.A. Franklin	"
	24	R.F. Hahn	"
	27	R.F. Hahn	"
	27	F. Daniels	"
	27	J.A. Moffatt	"
	27	J.S. Matsushita	"
	24	N.A. Harrison	"
	1 - 3	J. Lackner	New York
	29 - 30	J. Else	Westmount
	27	G.H.C. Mackie	"
	30	J.S. Matsushita	"
	30	J.A. Moffatt	"

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