KiwiSAT

Science Package Proposals

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KiwiSAT – Science Package.

Introduction:

Following two years of feasibility studies the Amateur Satellite Corporation of New Zealand's (AMSAT-ZL) confirmed its intention to build a Microsat class amateur communication satellite for launch into Low Earth Orbit (LEO). The satellite would be called "KiwiSAT". Once in orbit it would become part of the OSCAR (Orbiting Satellite Carrying Amateur Radio) constellation with a unique designation allocated by AMSAT-International. KiwiSAT would operate within the **Amateur Satellite Service** under the ITU Radio Regulations and would be freely available for use by the world-wide Amateur Satellite community.

In addition to its role as a communication system, the inclusion of a small science package was approved and with approximately 20% of the space frame volume set-aside for the purpose. Operation of the science package is to be secondary to the communication purpose and all data retrieved from the science package will be available via an AMSAT-ZL web page or can be directly downloaded by any suitable equipped receiving station. To meet the requirements of the ITU RRs, all software necessary to decode the data generated within the Science Package will be published as "Freeware."

This paper details the current state of the "KiwiSAT" project and provides details of the proposed science package and the internal facilities provided, or will be needed, for its support.

KiwiSAT - Details

The KiwiSAT space frame forms a rectangular box measuring approximately 240mm x 240mm x 280mm. Consisting of stacked individual trays, the completed unit will weigh approximately 12 kg at launch. Five trays make up the core communications satellite with a sixth "inverted" tray (referred to as the "Attic") on the nominal "top" (Z+) housing the Science Package." KiwiSAT is powered by a solar cell/battery system providing some 15 Watts of power.

The communication downlink uses two transmitters: A linear transmitter with a 30kHz bandwidth and a narrow band FM transmitter. Both operate in the 2 Metre Amateur Satellite Service allocation around 145.85 MHz. In addition a 100mW beacon phase linked to the 'working' beacon on 2Metres will transmit a signal in the 70 cm band. (*The combination will be used as part of the science package experiment.*)

Two onboard receive systems form part of the communications package, a 30 kHz bandwidth linear receiver for use with the linear transmitter as a general purpose transponder, and an FM Rx. Both are located in the Amateur Satellite Service allocation on the 70cm Band (435MHz).

In addition a 23cm Band (1.2GHz) receive converter will be flown to give an alternative uplink capability when the 70cm beacon is transmitting.

All frequencies to be used have been approved by the IARU Amateur Radio Satellite Frequency Coordinator. (*See appendix "J" for details.*)

Hardware.

Apart from the dedicated communications units, KiwiSAT sub-systems consist of:

- **IHU** (Integrated Housekeeping Unit). The IHU will provide for command housekeeping, the control of a 64 channel telemetry system and it will also process the various communication mode options. Additionally it will record and/or control - on demand from the ground – the data generated by the science package sensors.
- **BCR** (Battery Charge Regulator). The BCR is an autonomous unit that controls the satellite battery charge provided by the 6 solar panels. It also maintains the 12V and 5 V busses and supplies the various solar panel Current and Voltage values in the telemetry stream.
- **Flight Battery**. 10 in Number NiMh 4500 mA/h Suppo (China) cells are series connected to form the flight battery. These have been selected from a batch of 30 to give the best possible charge/discharge and capacity matching using a top end battery cell analyser. They are cycled monthly to ensure that they are in prime condition prior to launch.
- **ADAC** (Attitude Determination and Control). A range of instruments, housed in the "Attic", form the Attitude Determination Sensor Package providing support for the ADAC experiment that forms part of the KiwiSAT science experiment. A detailed description follows.

All the above KiwiSAT modules were completed in November 2010 and work is now concentrated on the provision of software for the housekeeping tasks (the Operating System) and for the support of the proposed science package.

Proposed Science Package.

The proposed science package for flight in KiwiSAT is in two parts.

1. To supply RF signals which – with suitable ground-station observation facilities – will enable precise measurements of the ionosphere to be made.
2. To carry out measurements and observations which will enable the satellites attitude to be determined and control to be exercised over its attitude. Attitude control will use the Earths geomagnetic field to orientate the satellite in accordance with commands from the ground.

It should be noted that the two experiments (above) are independent of each other and whilst the ionospheric experiment will be enhanced by positional information provided by the ADAC sensor package, this is a bonus. The attitude of the satellite is not relevant to the success of the ionospheric experiment.

Part 1. Ionospheric Characteristics Measurements.

In January 2007 I was asked to provide a keynote talk at the March 2007 Asian Space Conference held at the Nanyang Technological University in Singapore on the design and build of KiwiSAT. Immediately following an approach was made by the EADS Astrium team leader who was presenting a paper on Synthetic Aperture Radar (SAR) at the same Conference. He asked if Astrium could use KiwiSAT's beacon for some measurements in support of "P" Band SAR research. The research – to establish the advantages of "P" Band radar for biomass and ice thickness measurements - required a low Earth orbit signal on or around 435Mhz.

Whilst their use of our signals was totally open to them under the conditions of the ITU RRs, being approached by the third biggest Earth surveillance satellite producer in the World was seen as a compliment and very supportive of our efforts. I undertook to look at their request in detail.

In recognition of our assistance it was suggested that some help could be provided by Astrium in launch funding making the request even more attractive! (*At that time it was not our specific intention to fly a beacon on UHF (435MHz)!*)

The build team in New Zealand were immediately contacted and asked for the time and space penalties if we were to include a 435Mhz beacon. No major time problems were reported but it transpired the only position that was available for the additional beacon was the area that was being reserved for the "push forward" launch arrangements should launch costs/availability dictate we should fly with a provider other than Kosmotras (Russia) who offered the best deal. The "push forward" release system was that used by Ariannespace, the launch arm of EADS!

After some debate it was decided that KiwiSAT's involvement in a project of international relevance was seen as the overriding factor and our involvement would go ahead despite the loss of the launch funding assistance. We suggested that phase linking the UHF beacon signal with that on VHF could be beneficial to the measurements and this has been incorporated.

To be fully effective on a global scale it will be necessary for us to link into a European ground-station control project called GENSO (Global Educational Network for Satellite Operations) and this (its likely Beta testing will match the earliest launch date for KiwiSAT) will be of benefit to both science projects. Further work on this aspect is necessary and will be progressed as effort can be transferred from existing tasks.

Part 2. Attitude Determination and Control

A comprehensive system of Attitude Determination and Control (ADAC) equipment is to be fitted. Using the ADAC system, KiwiSAT will evaluate the concept of

a. increasing power generation capability in small satellites by use of the directional control of solar panels fitted to 'wings' and,
b. reliable active control of the satellites attitude which – if proven successful - would also allow directional ('gain') antennas to be considered on future flights.

The former would increase the power generation capability by a factor of two or perhaps three and the latter would give considerably improved communication link budgets.

(*These improvements do not apply to this KiwiSAT_1 as non-extendable solar cell sets will be flown on this mission with Omni-directional antennas engineered for best access.*)

Because of the importance of the KiwiSAT ADAC experiment to AMSATs "future build" policy, the remainder of this paper will concentrate on the development of sensors and equipment to support the ADAC system.

Proposed experimental Attitude Determination and Control System for KiwiSAT

Objective.

"To establish and monitor the orbit position of KiwiSAT using a range of onboard sensors and to control it's attitude using the Earths geomagnetic field via a magnetorque system."

Method.

1. By determination of the satellites orbital position and storage in the computer memory the outputs from the five specific sensors. All are either manufactured in New Zealand or are Commercial off-the-shelf (COTS) devices.

   They are:
   a. Sun Sensor's (Navigational and Target)
   b. Earth/horizon Sensors (Visible and Near I.R.)
   c. 3 Axis Magnetometer
   d. GPS Receiver (Lat/Lon. position and real time clock outputs)
   e. Low definition colour CMOS Camera
   f. Solar cell power generation panels

   (*See Appendix's A to F for details.*)

2. By the download of stored data from these sensors to a nominated ground-station as Whole Orbit Data (WOD) when the satellite is visible in NZ or (via the Internet) through nominated command stations worldwide.

3. By using the downloaded data to establish the satellites orbital position and its roll, pitch and yaw. To achieve this it will be necessary to prepare suitable software to integrate the sensor output readings using custom software. (*See Appendix K*)

4. By using custom software to prepare for upload a series of commands determined from the data obtained over one or a series of orbits and to use the commands to bring the satellite to a specified attitude by pulsing magnetorque coils that are fitted to the X-Y and the Z axis of the satellite. (*For details of the magnetorque coils and their operation, see Appendix H.*)

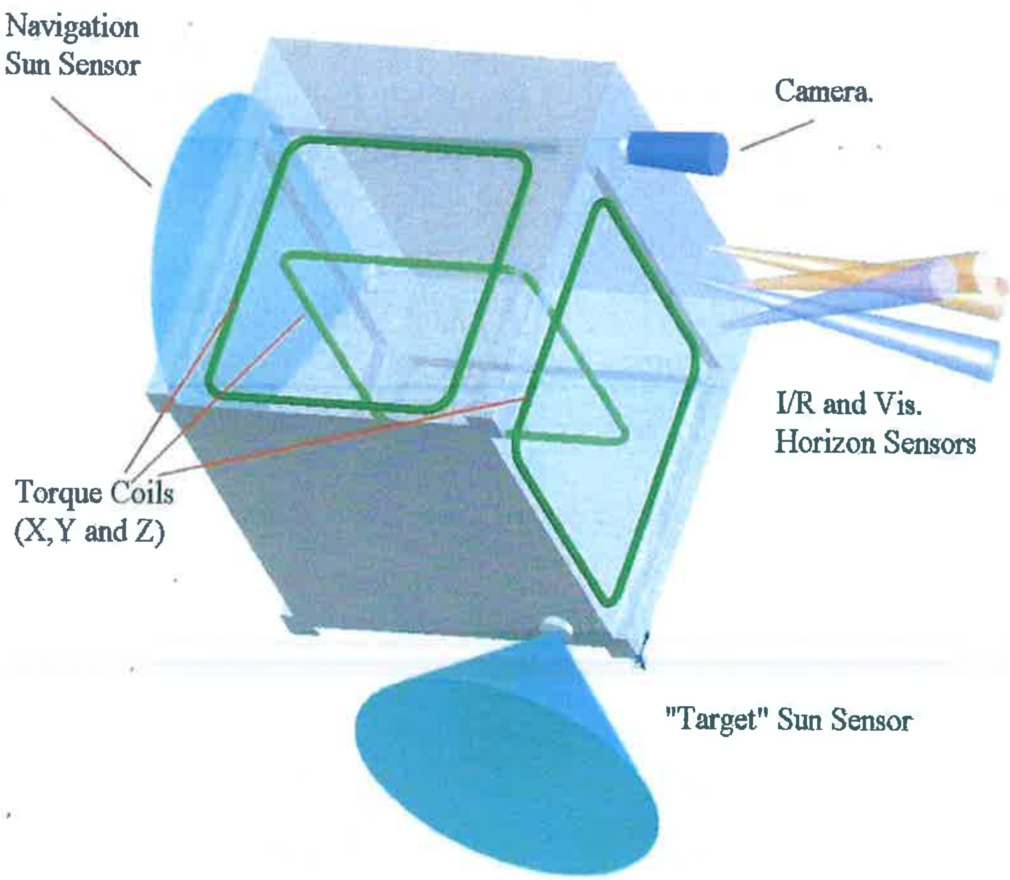
Project operation:

Once the system to control the satellites attitude has been proven and calibrated, it is intended to carry out a series of 'pointing' exercises using the Sun as a target. Of necessity these will have to be carefully controlled to ensure that the chosen 'target face' does not over heat. It is intended that the 'target face' will be the Z- or bottom/base face of the satellite. The Z- face is nominated for this purpose as it has a minimum number of solar cells – half the number to be fitted to any other side – and has clear areas that can be thermally protected. (*See Note 1.*) In addition there is also room on the "Z-" face for mounting the "Target" sun sensor to fine tune and measure the success of the attitude control whilst the experiment is in progress.

It is for consideration and investigation that attitude control of the satellite may be possible using a direct sensor/IHU link with the appropriate calculations being performed on board. Depending on the success of the initial ADAC experiments using ground-based calculation, this could be the subject in a second phase of experimentation to be carried out at a later date.

Note 1 The thermal design/stability of KiwiSAT is based on the satellite slowly tumbling or spinning to even out the temperature of the 6 faces. Interrupting this motion for extended periods could cause heat damage to the solar cells on the Sun facing side. The potential for this to disrupt the mission, long-term, must be minimized hence the choice of "Z-" as the sun pointing face for the experiment. Damage to (or total loss of) what is a 'half outfit' of cells on the bottom face would have the least affect on the overall mission.

The Fields of View of the various sensors are shown here:-



Appendix A

Sun Sensor

Two Sun Sensors are installed with the Navigational Sun Sensor on the X+ face of the 'attic' and the second, the Target Sun Sensor, on the Z- face of the satellite which forms the bottom (launch adaptor mounting) face.

Sun Sensor Description.

The two Sun Sensors are based on Hamamatsu 2 Dimensional Position Sensitive Detector elements (*Hamamatsu Type S 5991-01*).

Each sensor has a pinhole aperture positioned centrally above a 9mm square photo-sensitive surface which outputs a voltage proportional to the X/Y co-ordinates of the light spot impinging on its surface. By carefully choosing the gap between the pinhole and the photosensitive surface, the range of angular readings can be set to suit the usage requirement. Both sensors for KiwiSAT are set to give plus/minus 45 degrees cone.

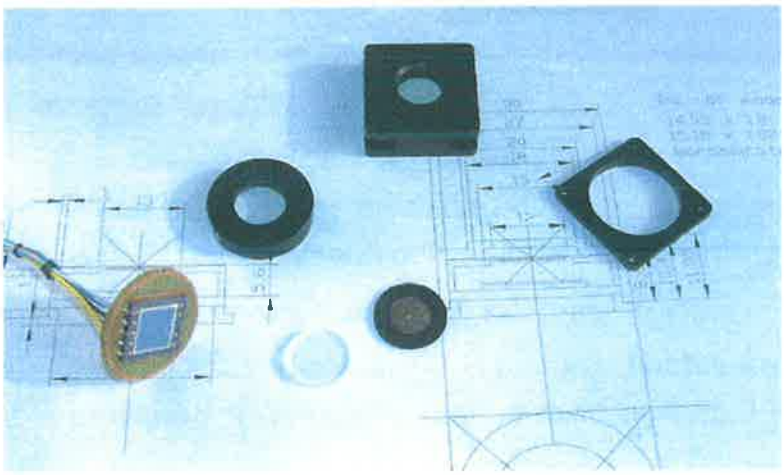
Analogue outputs from the sensors will be digitized using computational and A/D chips in the sensor electronics boards. These will be read and the information stored along with a time mark provided by the system (GPS based) clock.

In addition to its angular reading, a 3 state validation signal will be transferred in the telemetry stream to indicate the following states:- Sensor OFF, Detector current Out of Range and Signal Valid.

The sun sensors will be ground switch-able via a command uplink.

The Sun sensor heads and electronics have been subject to many weeks of validation prior to installation in the satellite for formal calibration as part of the pre launch preparation.

(*It is of note that the Hamamatsu PSD based system is currently in space and providing excellent service in the space environment.*)



Appendix B

Earth/Horizon Sensors.

The two Earth/Horizon Sensors are individual units mounted adjacent to one another with sensor elements sensitive to the visible light and near infra red spectrums.

They are mounted in the Attic on the "Y-" face of KiwiSAT.

Each sensor comprises two pairs of sensor elements – photo diodes for visible light and Dexter Research thermopiles for near infra red. The elements are set at an included angle of 22° such that each pair of light sensitive 'fields of view' (FOV) converge and cross at a point a few cm from the face of the 'Attic'. Each individual sensor has a 9° field of view. The distance between each "observed area/view" at 850km orbital height is 490kms.

By virtue of this configuration, the only light source/area in the Universe big enough to illuminate the sensor pairs at the same time is sunlight reflected from the Earth's surface. The associated electronics will output a 'high' (+5V) as each cell is illuminated by this source. The individual signals from each of the elements is amplified, digitized and included in the telemetry stream transmitted to the ground.

The order in which the two elements in each sensor head is illuminated and the timing between the two will indicate the speed and direction of movement of the satellite and the illumination of the second of the pair will occur when that sensor is crossing the horizon *.

The individual illumination of the cells by any other celestial object will not trigger the 'combined' Earth sensor output signal but may be of secondary value – this could be the subject of a further investigation or experiment. (*The Sun and Moon will certainly trigger the photodiodes individually and that may be useful. No experimentation of this aspect is currently being considered.*)

In general the angular level of accuracy of the earth/horizon sensor is low providing a "ball park" indication of the position of the Earth. The level of service this simple device will provide to the overall ADAC and the TEC and FR experiment will be established after launch. (*See also Appendix E – CMOS Camera*)

Calibration

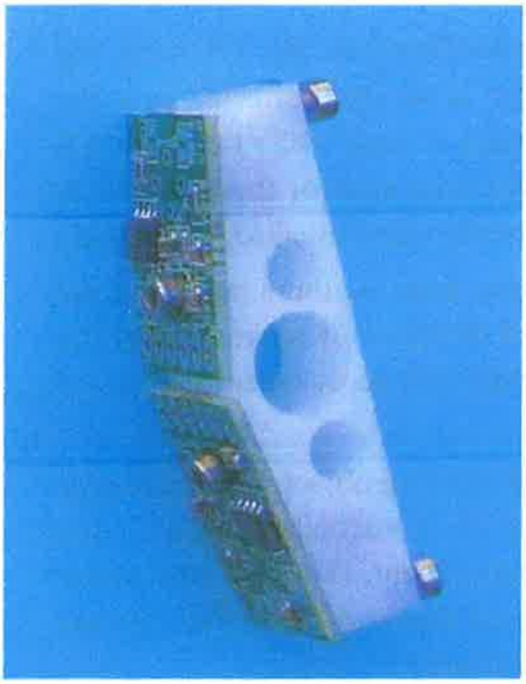
Considerable post launch work will be needed to calibrate and interpret data from this sensing device as its illumination will depend on a number of factors:

1 The rotational speed and direction of the satellite.

2 The orientation of the satellite whilst it is rotating. For instance, if it's rotating (tumbling) with its X-Y axis parallel (or nearly parallel) to the geomag-

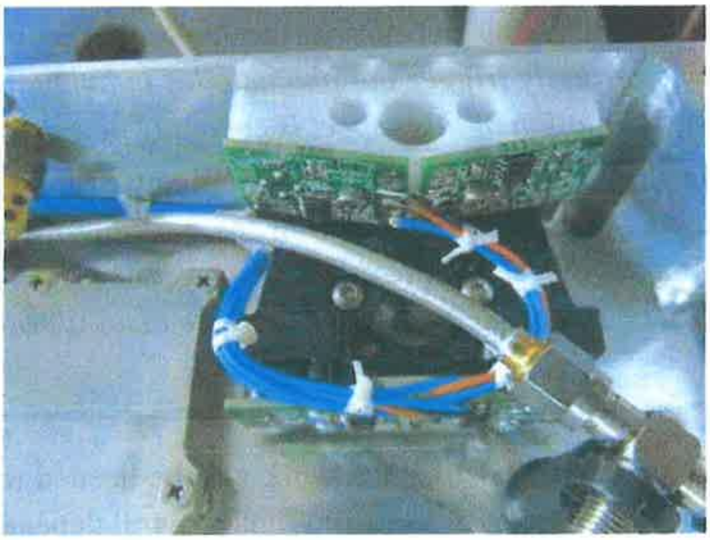
netic field (almost North/South) the sensing 'beams' will be sweeping the horizon "sideways" and both diodes will illuminate together! This is not a sought after orientation but it could happen when trying to point the Z- face at the Sun. This is not a particular problem: other sensors will supply the necessary outputs to provide data to confirm or refute the horizon sensor results.

3 The unknown effect that the gradual light reduction will have on switching as the sensor sweeps the day-night terminator. The sensing of light/dark when crossing the illuminated horizon (*atmospheric cusp*) is expected to be close to instantaneous due to the stark difference between the brightness of the Earth's 'edge' and deep space. When crossing the terminator, however, the light level will gradually fade and will at some point reduce to a level that will define the actual terminator line. (*The I/R sensor will not respond to the terminator crossing.*)



Infra red Sensor head

Visible light sensor



Horizon sensors installed in the Attic

Appendix C

3-Axis Magnetometer.

A Honeywell HMR2300 3-axis magnetometer is installed under the top "Z+" face of the satellite. This has a range of + or -2 Gauss and a resolution of <70μGauss. A heading resolution of 0.1° is claimed.

The data from this, used in conjunction with British and US Geological Survey data, is expected to provide good attitude data (*5° and 10° Lat./Lon resolutions are available using the IGRF field model*). Attitude changes using the magnetorque coils will be clearly displayed by this unit.

Readings will be time tagged and stored for download on ground command.

Magnetometer readings must be controlled to take place between magnetorque pulses; an interlock system will be required in the software. This is not seen as a particular complication.

The magnetometer is fitted with a reset system. This will be actuated routinely to ensure that no offsets are induced into the head by repeated operation of the magnetorque coils. Ground testing has shown that whilst the readings are (*understandably*) corrupted when the magnetorque coils are energized, the magnetometer readings return to normal within a few milliseconds of the pulse or pulses dying. No permanent offsets are induced in the head by the magnetorque flux levels to be used, indeed, a very substantial permanent magnet is needed in close proximity to the magneto-resistive material in the head to permanently offset it. Notwithstanding, the reset facility in the head is not particularly power hungry and will still be operated at intervals to ensure accuracy.

Honeywell Magnetometer head – unmounted.

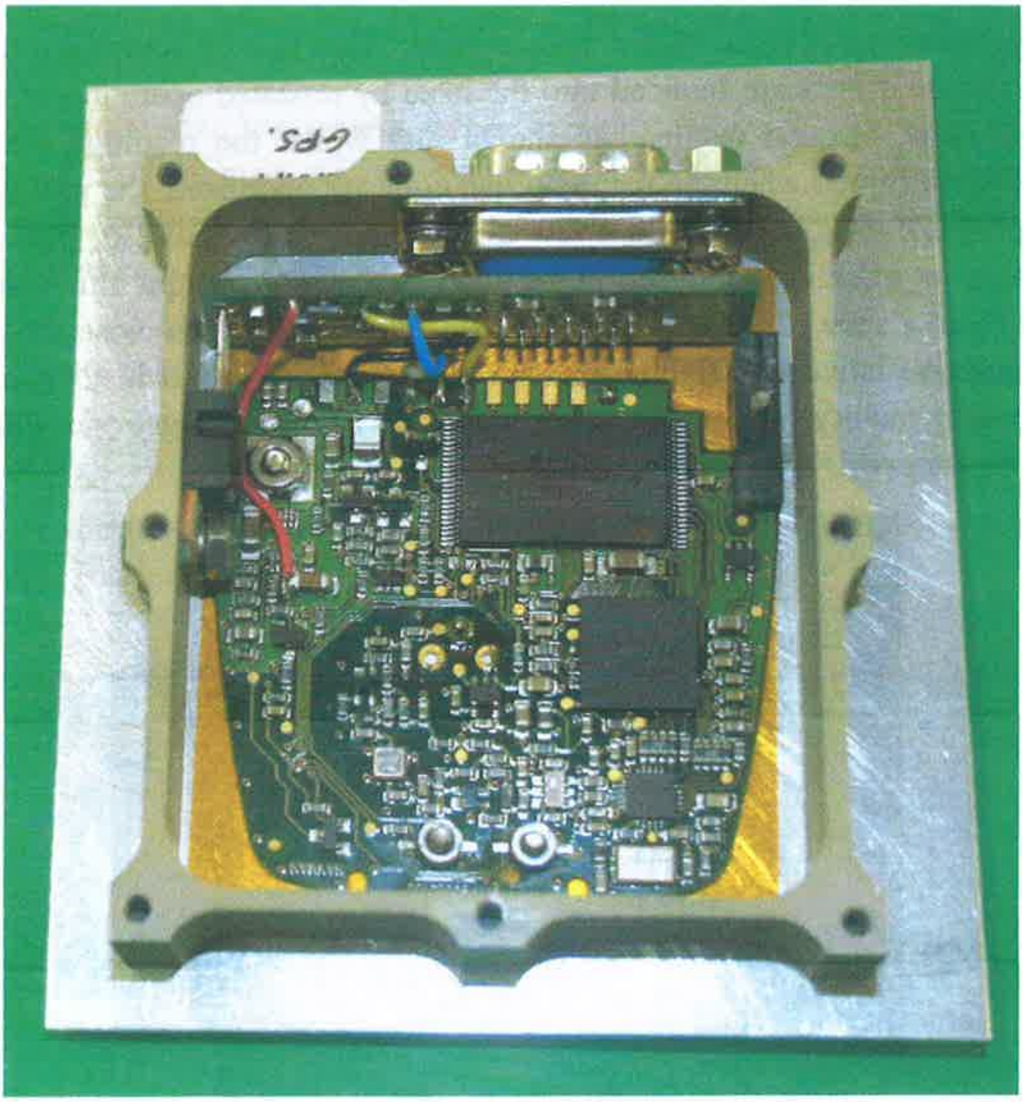
Appendix D

Gobal Positioning System receiver.

This is a specially prepared Navman GPS receiver fitted with high speed/high altitude software written and tested on a GPS evaluation system at Navman. The results are proven for use in LEO at 850km altitude. The software is held in flash memory and can be reloaded should it become corrupted by radiation or fast particles whilst in space. (*This is unlikely but tantalum foil screening has been attached for added protection to the top and undersides of the two major IC's.*)

In addition to using the GPS for positioning information, it will also provide a real time clock input for the flight computer/data which will be used extensively for the ADAC sensor data. It is intended that the GPS clock will be used periodically to update the onboard flight computer clock system; the GPS will not run continuously.

The data output format is to the "NMEA" Standard



Appendix E

CMOS Camera.

The inclusion of a CMOS Active Pixel Sensor (APS) camera is to provide a sensor "confirmatory tool." It is not envisaged that any serious ground imaging will be attempted.

The camera is situated alongside the earth/horizon sensor on the "Y-" "Attic" face and its primary use in support of this device. A similar unit (*the YACE camera*) was used extensively for the same purpose during the recovery of AMSAT satellite AO-40 (Phase 3D) and the pictures it produced significantly raised the level of confidence within the recovery team when they were determining the satellites attitude for the change-of-orbit firing of the rocket motor.

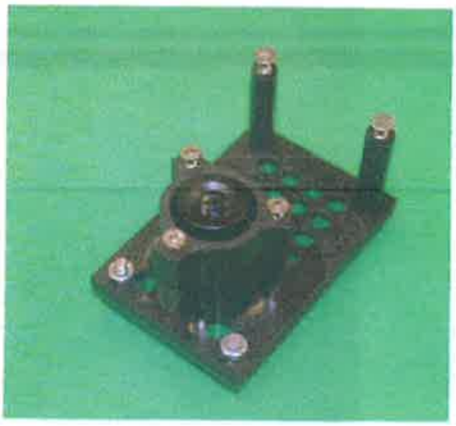
An example of its use would be to verify the point of switching of the 'trailing' earth sensor element as it transited the space/horizon region. (*See Appendix B*) This is expected to provide a sharp transition image with the horizon line at an angle related to the attitude of the spacecraft. Its "trigger level" as it transits the day-night terminator line is less clear-cut and the camera could, perhaps, be used to establish the switching light level as it traverses.

If interest is sufficient, the camera will be made available for simple earth imaging on completion of the main ADAC positioning experiments. No special provisions will be made for this and further software would be required to make this possible, should interest be sufficient and a volunteer come forward.

The camera unit chosen was based on the CubeSat XI-IV which was built and operated very successfully by University of Tokyo. It is still providing good images after 5 years in space – not bad from a unit costing less than US$60!

The chips (and a lens unit) were obtained by Clayton Gumbrell (ZL3TKA) who re-engineered the board to suit the layout and mounting system used in KiwiSAT. The images obtained are excellent.

Initial camera test results – terrestrial!

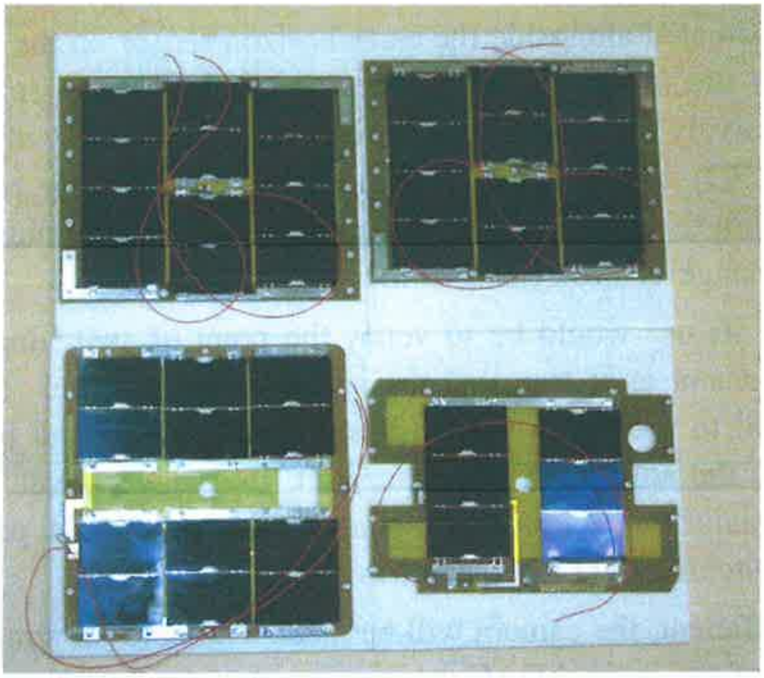


The re engineered camera.

Appendix F

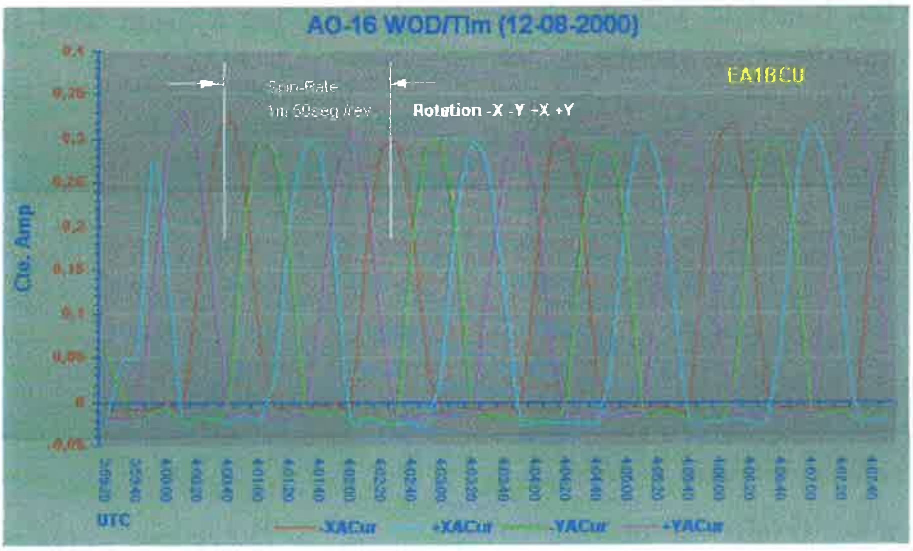
Main Solar Cell Panels,

With Solar cells situated on all 6 sides of the satellite a broad "sun direction" can be established from their outputs and from these a rough determination of the satellites attitude and rotation (*spin*) can be made. The current generated by each face – together with a time mark – will be included in the telemetry stream.



Four of the Six panels

An actual example of plotted Solar Cell Current readings is below. This was downloaded from AMSAT AO-16 ("PacSat"), a microsat almost identical to KiwiSAT in size and shape that is flying in a similar orbit to that planned KiwiSAT. The panel current output on the X and Y faces show clearly the spin direction and period



Appendix G

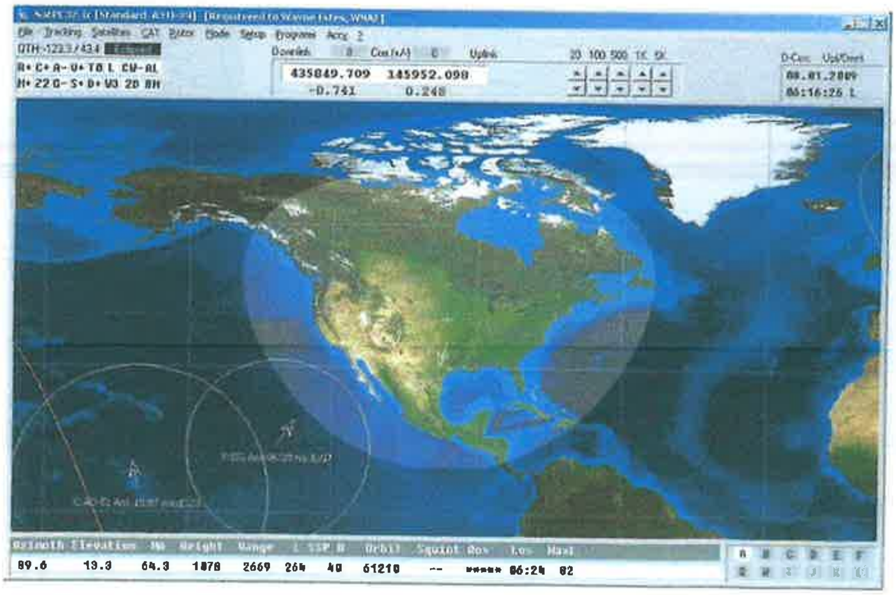
Basic tracking of KiwiSAT – Software

It is the responsibility of the Launch Agency to place KiwiSAT into its contracted orbit and provide the initial positional and attitude information on release. The general tracking of the satellite from the release point is then the responsibility of the owner – AMSAT-ZL

Based on the launch window, a set of preliminary Keplerian Elements ("Keps") will be issued and insertion of these into a tracking program (of which there are several available) will enable the KiwiSAT to be acquired and controlled using appointed ground command stations. Within a few days, the launch Keps will be followed by an official NORAD set. NORAD will track KiwiSAT continuously from that moment on. A fresh "Kep set" will be issued every few days and these will appear on the Celestrak:- http://celestrak.com/NORAD/elements/.

All satellite tracking programs currently available will provide minute by minute positions for the satellite throughout its orbit and these are accurate in position and altitude to within a "few tens of kms". The tracking programs "InstantTrack", "Quicktrack" and "SatPC32" can be obtained from AMSAT-ZL and copies will be obtained and supplied to those needing them in the development of the software package for KiwiSAT.

All the above tracking programs are capable of providing printed pass information sheets and some are able to output the data directly into antenna tracking and frequency (*Doppler*) correction control systems. The degree to which they can be integrated into other forms of software (should that be required) is not known. However the writers of the tracking software quoted are Radio Amateurs themselves and should the need arise I'm sure they would help with advice (and perhaps source code) should we approach them.



Appendix H

Magnetorque Coil System

Having established the satellites attitude and motion using the on board sensors it is intended to control and point the satellite using electromagnetic coils built into the body of the satellite.

Experiments using a single axis magnetorque mock-up indicate that good directional control should be possible using quite modest coils and low current. As a result of this 3 air cored 'frame' coils have been produced and fitted. Two are outside the spaceframe and under the X- and Y- solar panels. The third – for the Z Axis - is attached to the base of the battery tray.

The current in the coils is controlled by 3 driver boards – also in the battery tray – which are based on control IC's for stepper motors. To effect the required movement of the satellite it will be necessary to apply short power pulses to the coils as appropriate to their orientation with respect to the geomagnetic field. The timing, length and orientation of the pulse – and its current direction - will be initially determined from the information provided by the various sensors in Appendixes A to E. The length of pulses will be adjusted and refined by measuring and recording their effect on the satellites attitude as indicated in subsequent readings/passes.

(To ensure that (in a failure mode) a coil or coils are not left energized the drivers are activated by a pulse stream from the IHU software. Any interruption to this stream will cause the coils to switch off.)

Whilst the ability to control the satellite in this manner is in no doubt, the degree of accuracy to which this can be done will depend on the level of accuracy of the sensors and the ability to which these can be used in an appropriate algorithm or algorithms. It will also depend on the battery power available bearing in mind it will be necessary to maintain the other essential housekeeping and communication services at the same time.

X Coil Driver in Battery Tray

X and Y Coils in spaceframe.

Appendix I

List of Downloaded Measurements/states needed for the Science Package.

Sun Sensors.

Navigation .	Sensor Off X Position Y Position Detector Current out of range Signal Valid
Target	Sensor Off X Position Y Position Detector Current out of range Signal Valid

Earth/Horizon Sensor

Visible	Sensor Off Diode 1 Illuminated Diode 2 Illuminated Both Diodes illuminated (*May not be necessary to download – used only for internal (direct) attitude control.*)
Infra Red	Sensor Off Diode 1 Illuminated Diode 2 Illuminated Both Diodes illuminated (*May not be necessary to download – used only for internal (direct) attitude control.*)

3-Axis Magnetometer.

	Sensor Off X-Axis (G) Y-Axis (G) Z-Axis (G) Output 16 bit Digital (Binary, BCD or ASCII) (*Honeywell HMR2300 Application Sheet for full details/command set*)

GPS Receiver

Rx Off

Time + Lat/Lon/Altitude data.

(*Format to be to NMEA Standard.*)

Colour CMOS (APS) Camera.

Camera Off

Camera armed/ready.

Digital output.

Main Solar Cell Panels

Z+ Current

Z- Current

X+ Current

X- Current

Y+ Current

Y- Current

Value (mA) for each item in the Main Telemetry Frames as in existing MicroSAT software.

Appendix J

KiwiSAT coordinated communication frequencies:

Transmit frequencies (Downlink)

Linear Transponder	145,850 ~ 145,880 MHz
FM transmitter 9600 bps data	145,865 MHz
FM Transmitter FM voice or 1200 bps packet	145,865 MHz
Beacon 1 CW	145,885 MHz
Beacon 2 (Data)	145,865 MHz
Beacon3 (Data)	145,865 MHz
Beacon 4 9600 bps data	437,425 MHz

Receive frequency (Uplink)

Linear Transponder 1	435,260 ~ 435,230 MHz
Linear Transponder 2	1268,880 ~ 1268,850 MHz
FM receiver 1	435,245 MHz
FM receiver 2	1268,865 MHz

Amateur frequencies are shared frequencies and due to the limited spectrum available some projects will share the same frequencies.

This document confirms the frequencies coordinated by the IARU Satellite Adviser and Advisory Team. The builders of the satellite must comply with all the regulations currently in force in their country and follow local licensing procedures.

Appendix K

Software preparation.

Basic requirement for the Flight Computer software.

A suitable software package is required to provide control over the satellite systems and provide an appropriate telemetry stream from which to assess the state and health of the satellite. This is in hand with a small team being led by Clayton Gumbrell (ZL3TKA). It will be robust and have a "fail safe" facility for returning to a default command condition in the event of uplink errors or failures of parts of the internal systems. A reset to defaults will be available by ground command and also to be activated automatically when the satellite detects a significant abnormality. A "watch-dog" system commonly used by AMSAT relies on the absence of any detectable command uplink activity over a period of (say) 72 hours. It then assumes loss of control and initiates a reset.

Science Package operation requirement.

Aside from the control of the spacecraft "housekeeping" duties (OS), a specialized application software package for the control and operation of the ADAC (and the science experiment equipment) will be required.

This could provide a number of very challenging projects in the field of computer science and control engineering and its extent would be limited only by the imagination of those involved and the capability of the in-flight computer (IHU) hardware. Initial work on the mechanics of the system has been started by KiwiSAT team member, Dr Jon Henderson and it is now essential to set up a team to provide the necessary control software options. The provision of software for the ADAC aspect of KiwiSAT's operation is not a pre launch necessity but it's prudent to get at least a basic control package together before launch. A number of openings are being investigated.

For guidance the following notes outline the Science Package requirement. They are my personal assessment of what will be needed and will hopefully assist those working on the hardware design.

1. At the moment of separation from the launch vehicle the maximum roll, pitch and yaw details will be known. For a Dnepr (SS18) launch the agency will ensure that the initial angular motion of the satellite at the moment of separation from the launch vehicle is within the following limits: ± 1.5 degrees for angles of roll, pitch and yaw; and ± 0.5 degrees/second for rates of roll, pitch, and yaw. In addition the spacecraft's Keplerian Element Launch set will be

confirmed and from them the satellites position Lat, Long and Altitude will be continuously available via InstantTrack or one of the other tracking programs. Its illumination state (eclipse or illuminated) will also be known from either QuickTrack or Predict. After a short delay for initial out-gassing, the 2 Mtr (144MHz) identification Beacon in the satellite will be switched on. A period of several hours will then be allowed for the spacecraft to fully outgas. On completion of the out gassing, a telemetry stream will be activated in the downlink.

2. Once activated it's suggested that the data system should be commanded to record WOD whilst downloading the standard telemetry in real time. A 'rough' estimate of the satellite's attitude and spin direction/rate will quickly be possible using the solar panel current telemetry information and confirmatory information will be available from the Sun, the earth/horizon sensors and the magnetometer - all of which can be commanded on, or 'cycled', to provide data. The extent to which each can be used will depend on the power budget.

Whilst one or two passes will provide enough data to get a 'feel' for the basic attitude information it will be necessary to accumulate a number of WOD files before a more accurate, mathematical statement of the satellites motion could be attempted. It is suggested that the most convenient means of establishing an accurate initial assessment of attitude over a series of orbits will be by means of the magnetometer.

3. Various Geomagnetic Models are available giving 3-axis information of the geomagnetic field around the Globe against which the output of the satellite's 3 axis magnetometer could be compared. Running this comparison would give a series of timed offsets, which could be plotted and form the basis of a graphical or tabular display/record showing the spacecraft's motion.

4. Some means of displaying this motion graphically would be of great value and interest and work on this is nearly complete with excellent graphics showing KiwiSAT on screen with movement based on the solar panel voltages/currents. (This has been developed by Andrew (ZL1AVC) with help from Design Solutions.co.nz and Dr Jon Henderson)

   This will be further developed to display the entire telemetry as it is downloaded live.

5. Having established the angular position of the satellite relative to the magnetic field at any instant (by using the full range of sensors available on the spacecraft), the selection of the appropriate magnetorquing coil or coils and the calculation of the direction and timing of pulses to obtain the maximum torque for attitude adjustment, should be possible. The development of user-

friendly control software will be challenging not only to prepare but also to calibrate. (The exact behaviour of the satellite under magnetorquing conditions will not be known until the launch and will probably require considerable experimentation. However, with known mass and inertia of the spacecraft, known magnetic moment available in the magnetorque coils and the known IGMF it is believed that a good control model could be prepared by a person with the appropriate mathematical background.)

END

Comment on the above is welcomed and should be directed to me at my home email address: fredk@kcbbs.gen.nz.

Fred Kennedy, ZL1BYP, KiwiSAT Engineer, AMSAT-ZL.

Remit - Transmitting

Part 9 - Amateur Radio Emergency Communications

9.1 Amateur Radio Emergency Communications

a. The Executive Council shall establish by regulation a Charitable Trust to be known as the NZART AREC Emergency Funds Charitable Trust which, under the direction of the Executive Council, is entrusted to hold monies and grants from New Zealand Search and Rescue Council (NZSAR) (and possibly also monies and grants received from other entities) and take responsibility to NZSAR, NZART, and other entities that may make a grant for the application of the funds in accordance with any conditions NZSAR and other entities attach to the grant while achieving paragraph 1.2 i. of the objects of the Association.

b. Any Trust so established shall be incorporated as a Charitable Trust Board in accordance with the Charitable Trusts Act 1957.

c. The Trust's primary function will be to receive funds for delivery of emergency services specified in the Service Level Agreement (SLA) between NZART and the Ministry of Transport. Additional clauses

d. The Executive Council may establish by regulation a sub-group to be known as the Amateur Radio Emergency Communications (AREC) which, under the direction of the Executive Council, is entrusted with achieving paragraph 1.2 i. of the objects of the Association.

e. Any sub-group so established must be divided into Regions, Districts and Groups (Sections) as required under the control of an AREC Chief Executive Officer to be a pointed by the Executive Council.

f. Each group (Section) must be attached to a Branch as its home Branch but may cover multiple branches and the regulations are to provide generally for the mode of attachment and necessary policy and guidance to ensure National consistency with delivering AREC services that are safe, competent and sustainable.

g. The regulations may also provide for matters which are to be left to the constitution of an individual Branch, that nothing is to be included in the regulations or any Branch constitution which could impair the operational efficiency of AREC.