KiwiSAT

A Communications Satellite for New Zealand

Presented by

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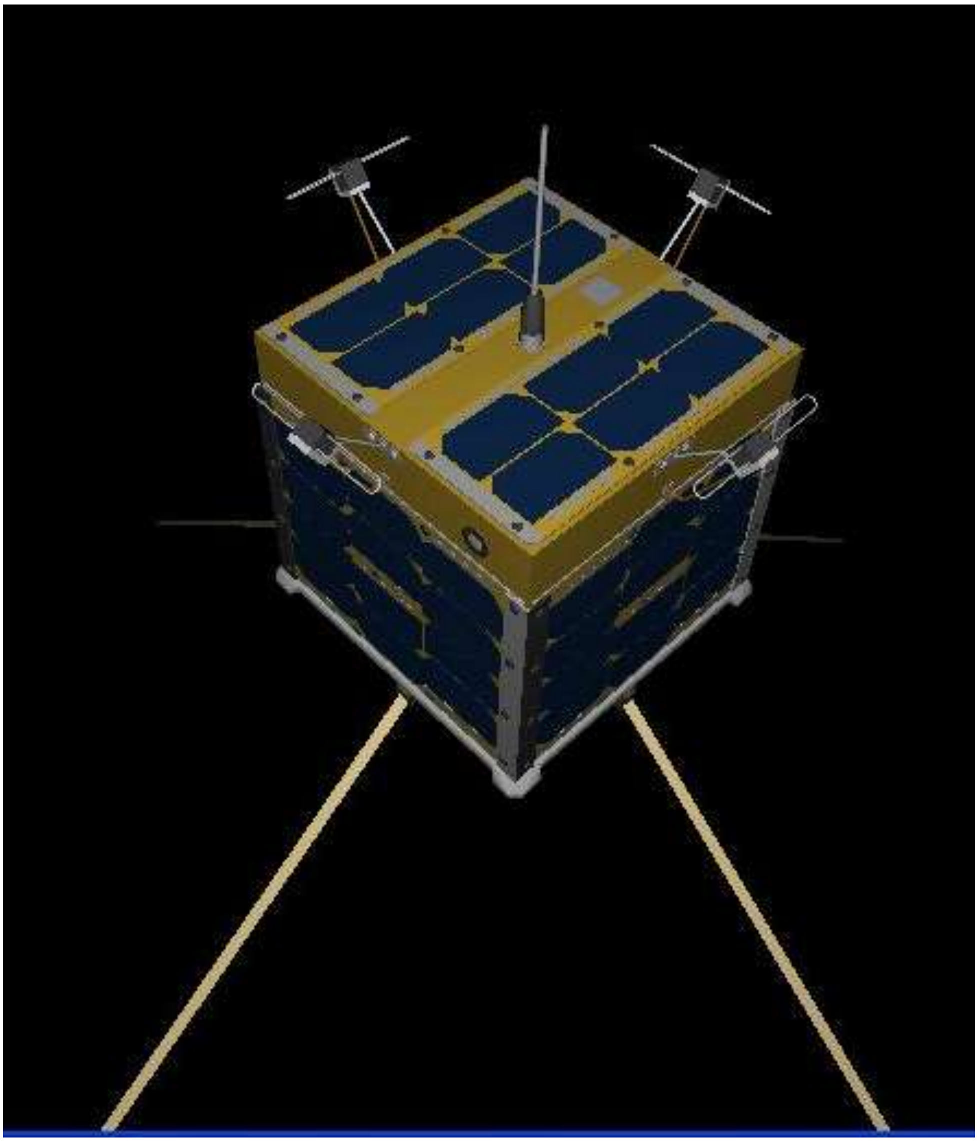
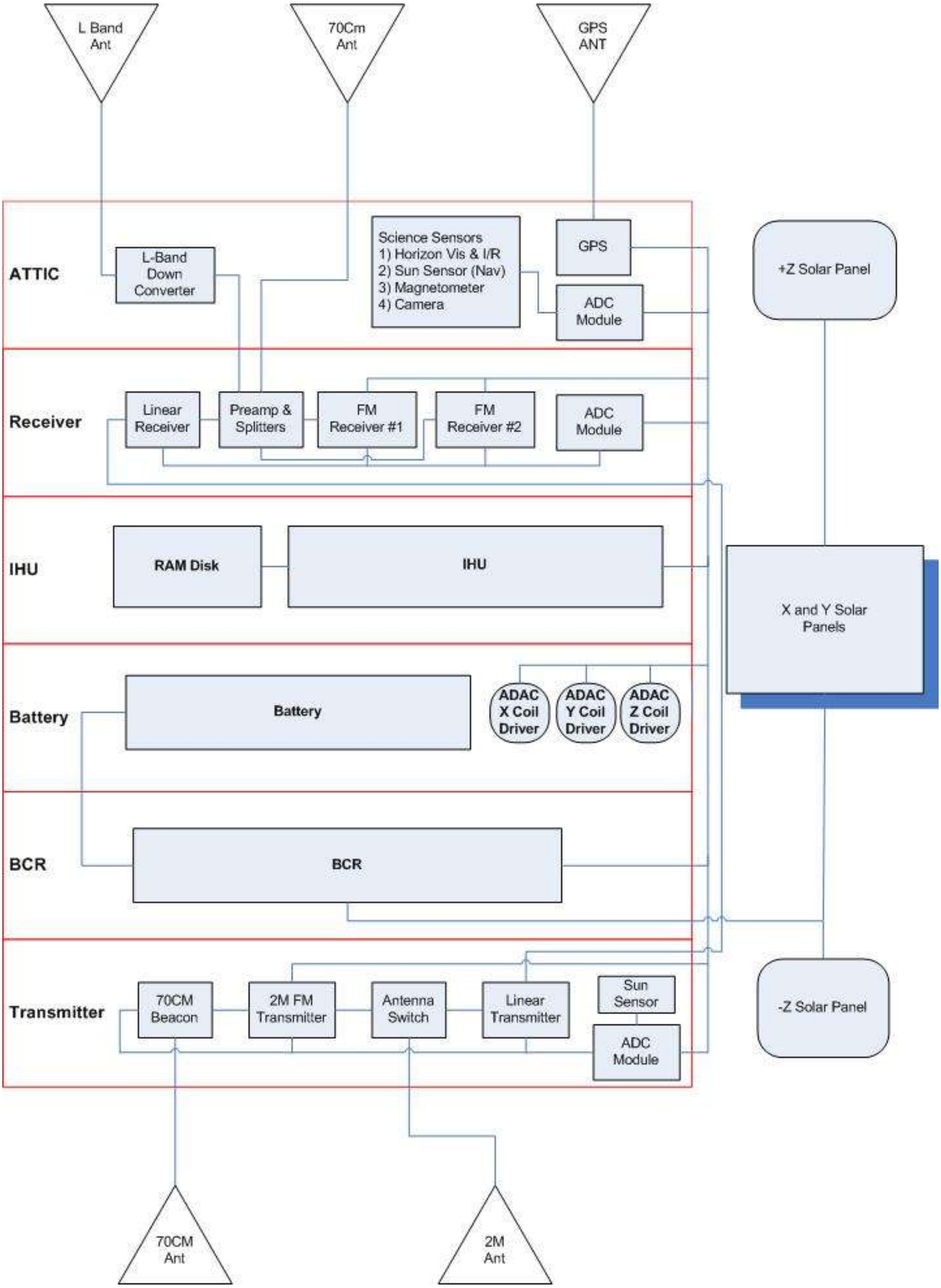
Abstract

KiwiSAT is a MicroSAT class satellite designed and built by AMSAT-ZL (New Zealand). This paper reviews progress in its construction.

April 2009



KiwiSAT Block Diagram



KiwiSAT

A Communications Satellite for New Zealand

Introduction:

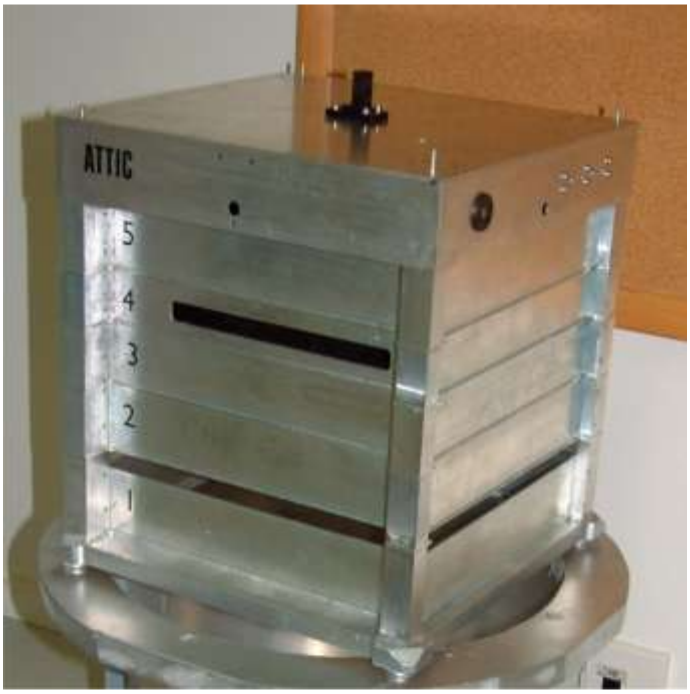
The first idea for an Amateur Satellite came from the 1999 NZART conference at which Lyle Johnson KK7P was present.

AMSAT-ZL took on the challenge. The first design considered was for a CubeSAT (100 mm cube), but this was discarded and it was decided to proceed with a MicroSAT sized (230mm cube) satellite based on the AMSAT-NA MicroSAT's.

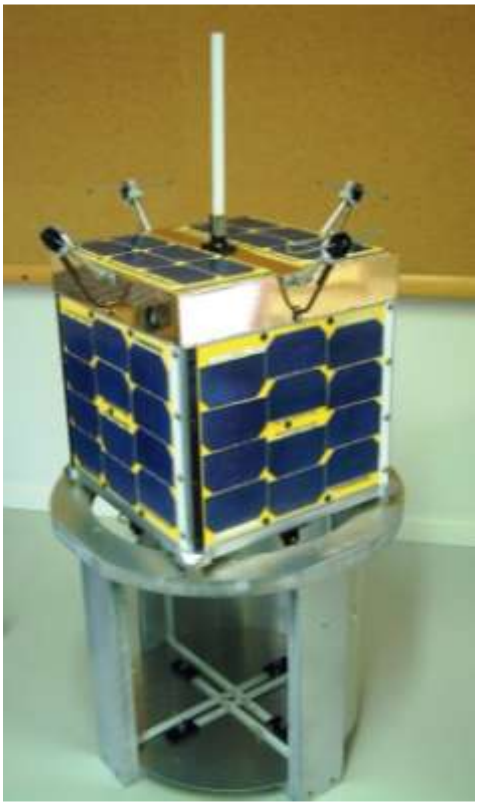
This paper is a progress report on progress to date (April 2009).

Spacecraft Frame:

- A stack of five fabricated aluminium trays each 237 mm x 237 mm plus an 'attic'
- The height of each tray varies from 25 – 44 mm making a total of 237 mm also.
- Nominal useful internal area in each tray is approximately 210 mm x 200 mm
- RF cables plus a wiring harness carry power, inter-module data, telemetry, and control signals.
- Four rods running the height of the spacecraft bolt the assembly together.
- Satellite's surface area to be covered by solar cells
- All unused surface area (including the "attic") is covered with thermal absorbing or reflective tape.



KiwiSAT Frame (Engineering mock-up)



Final Design Model

Note: The solar cells used on KiwiSAT will not have the corners chamfered. Rod shaped 70cm antennas fitted to both top +Z and bottom –Z faces.

KiwiSAT Modules:

From the top down –

Attic: Antennas (70cm & 23cm), Magnetometer, A/D Converter, Horizon & Sun Sensors, GPS Receiver, CMOS Camera, L band receive converter & antenna harness.

Tray 5: UHF Linear Receiver on 70 cm, 2 FM receivers (70cm), Preamp, and A/D unit.

Tray 4: IHU (Integrated Housekeeping Unit – Flight Command Computer) with integrated 1200 and 9600 baud modems and Ram Disk.

Tray 3: Battery tray contains 10 NiMH cells for 12 volts at 4.0 Ah and Z Magnetorque coil and three coil driver boards.

Tray 2: Battery Charge Regulator (BCR).

Tray 1: 2 m transmitters (Linear & FM), 70cm beacon, Sun sensor & electronics, A/D units, Antenna switch, Antenna matching units, VHF antenna supports (4 blade turnstile), UHF antenna support (Monopole) and two release power switches.

Tray 5: *70 cm (U Band) receivers and 23 cm receive converter*

KiwiSAT Linear Transponder – UHF receiver designed by Terry Osborne ZL2BAC modified by Phil Wakeman will be used as the primary operational mode as part of the Main Transponder.

- 30 kHz bandwidth will handle up to 10 simultaneous SSB QSO's
- HP MMICS used ~25 dB gain, unconditionally stable.
- Ring Mixer.
- Toko Helical Filters.
- NDK IF filter – very good specs.
- AGC from Analog Devices VGA. 45 dB gain reduction possible.

U Band receiver:

435.260 to 435.230 MHZ

The 23 cm receive converter is still under construction.

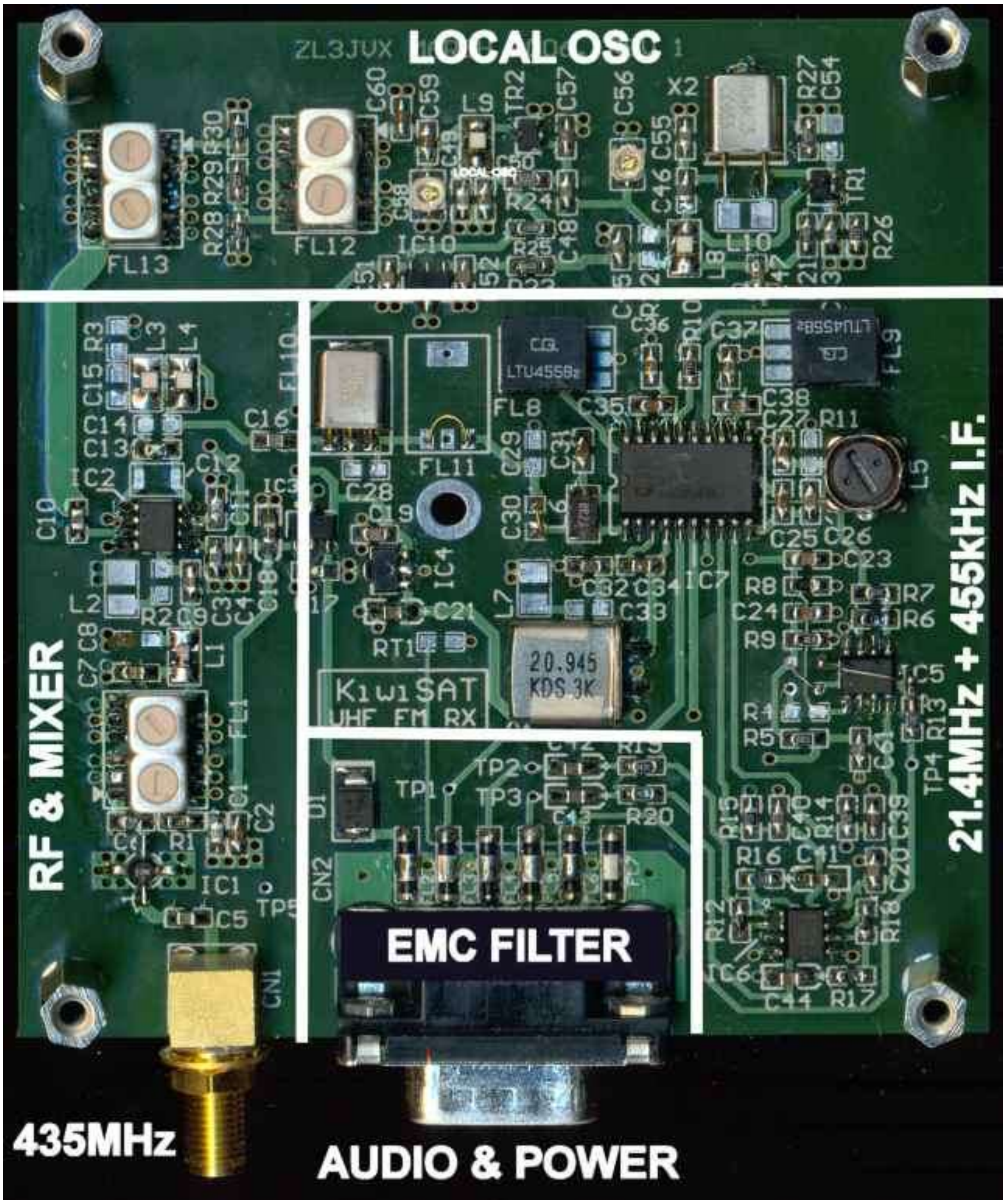
L Band receiver:

Uplink frequency:

1268.880 MHz to 1268.850 MHz

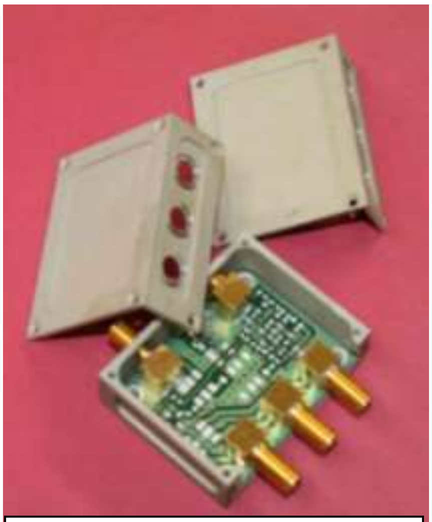
U Band (70cm) Linear receiver

In the same tray are the two FM UHF receivers designed by Mark Atherton ZL3JVX.



This unit when combined with the 2 metre FM transmitter will provide a similar service as AO-51 or AO-27 except that KiwiSAT will be mode U/V.

Uplink Frequency 435.245 MHz



70cm Preamp and Splitter box

Tray 4: IHU Integrated Housekeeping Unit

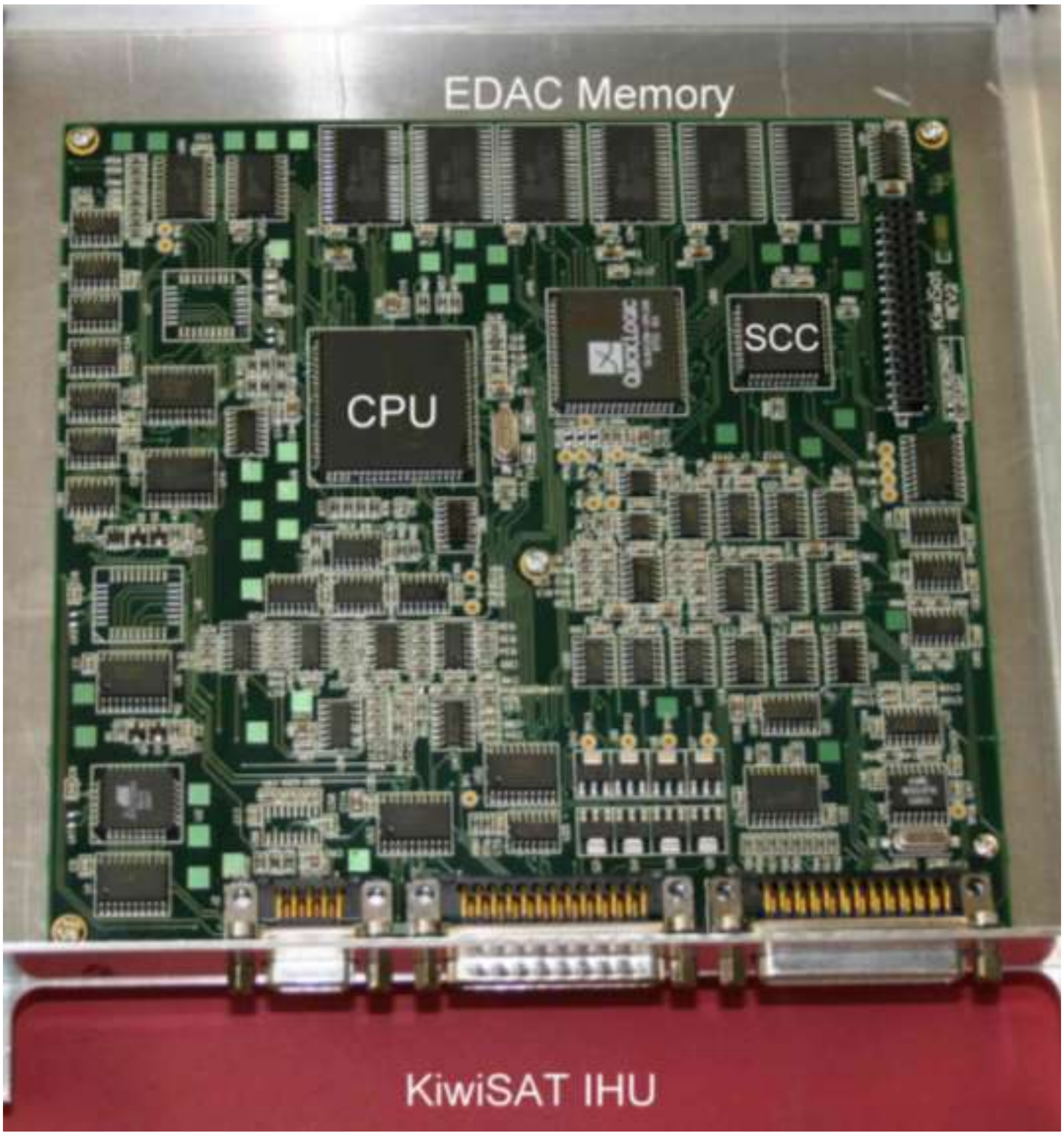
The circuit for this unit was designed by Lyle Johnson KK7P for AMSAT-ZL. It was designed to be as close as possible to the older V53 design and to make the porting of the SCOS operating system as easy as possible.

The processor is an Intel TN80C188EB-20 running at 7.373 MHz with a 12 Megabyte RAM disk.

Layout and design of the PCB was undertaken by a group in Wellington led by Terry Osborne ZL2BAC

The RAM Disk is mounted above the IHU.


RAM Disk 12 Megabyte



General Specification of IHU (Integrated Housekeeping Unit)

Radio Mod/Demodulators: 1 x 1200 bps standard AFSK AX25 packet radio modem, (Chip is MX614), 1 x 9600 bps FSK AX25 packet radio modulator with 2 demodulators.
Memory: 1M byte EPROM, 12 Mbytes RAM and 1M byte of EDAC protected RAM.
CPU Microprocessor: INTEL TN80C188EB20
Operating System: Boot loader with locally designed operating system.
Crystal Frequency: 14.7458 MHz divided by two = 7.3729 MHz
Serial Ports: 1 x RS232 (for initial programming), 4 x SPI (for Telemetry/data and forward control of spacecraft modules.
Parallel I/O Ports: 24 digital I/O ports.
Connectors: Two DB25 connectors and one DB9 for CMOS camera interface.
Operating Temperature: Minus 10 degrees C to plus 60 degrees C.
Size: 190 x 204 x 25 mm. (1 module size)
Mass: < 0.2 Kg, Vcc: 5 Volts. Power Consumption: < 1 Watt.

Tray 3: Battery

Comprises:-
Power generation: 66 multi junction photovoltaic cells will be used to charge the cells

Battery: 10 x 4.0 Ah NiMH with a nominal battery voltage of 12 V DC. Flight ready set obtained from AMSAT-DL.

Backup set of Suppo NiMH cells.

Included within the battery tray will be the Z axis magnetorqueing coil and the three coil driver boards.

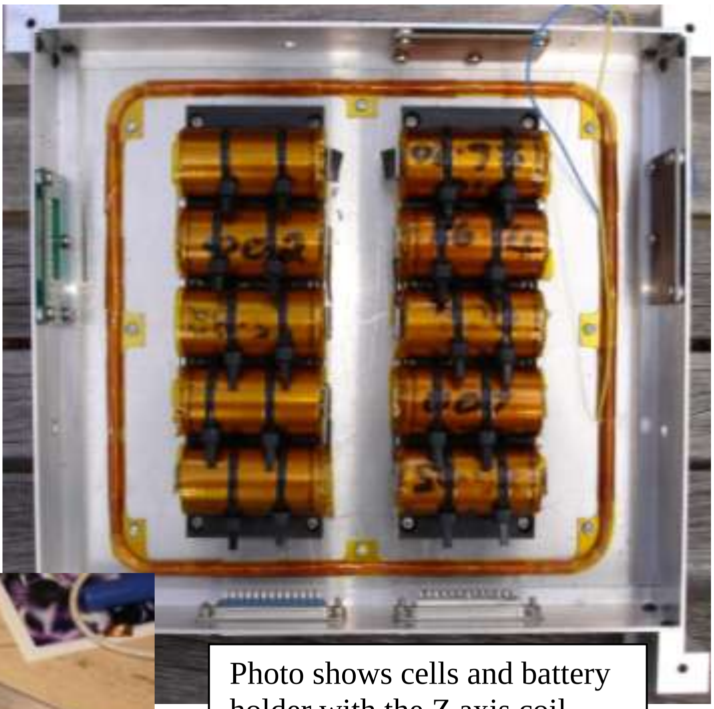
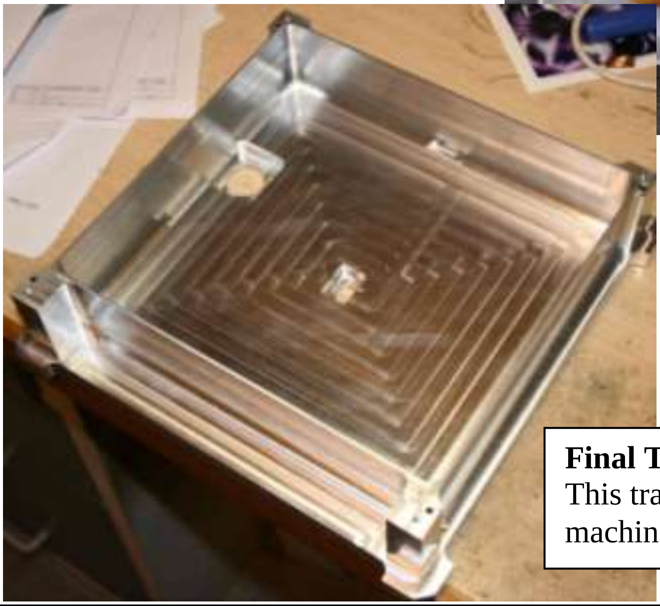


Photo shows cells and battery holder with the Z axis coil.



Final Transmitter tray in finished state. This tray has been milled out on a CNC machine from a solid block of Aluminum.

Tray 2: Battery Charge Regulator (BCR)

Used to manage battery charge and protection.
Switch mode design with 89% efficiency.
Operates autonomously.

IHU used to fine-tune default parameters.

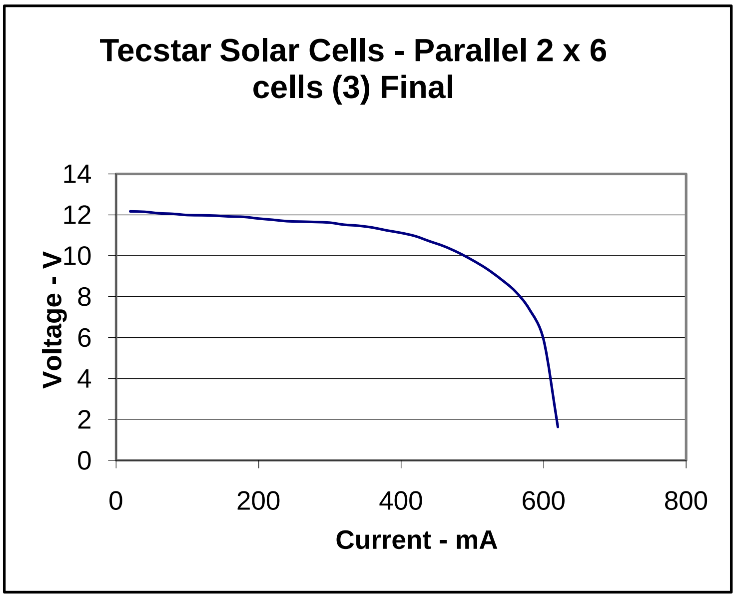
The "Smart Battery Charger" incorporates Maximum Power Point tracking in its design to capture every drop of available energy from the photovoltaic cells.

Designed and built by Hans Holtz ZL1HB

A temperature monitoring thermistor is on the end of the blue wires.

Solar Cells:

Tecstar Dual Junction Cells



Measured performance at Whangaparaoa

Efficiency 22% minimum at Beginning Of Life (BOL).

Power out per cell 0.86W at 28 degree Celsius in Air Mass 0.

66 cells required to cover the six sides.

Tray 1: 2 metre transmitters and Secondary Sun Sensor.

Linear VHF 2 Watt PEP transmitter is designed for a 30 kHz bandwidth (Phil Wakeman and Terry Osborne ZL2BAC).
Features:
Ring Mixer and Toko Helical Filters.
MMIC ERA3 used.
High Side L/O.

M57732 Power Block used as the final amplifier. This has a very good output filter with no 3rd harmonics.

U (70cm) band beacon on 437.425 MHz. The UHF beacon transmitter will be phase linked to the two metre FM transmitter and will have an output power of 150 mW.

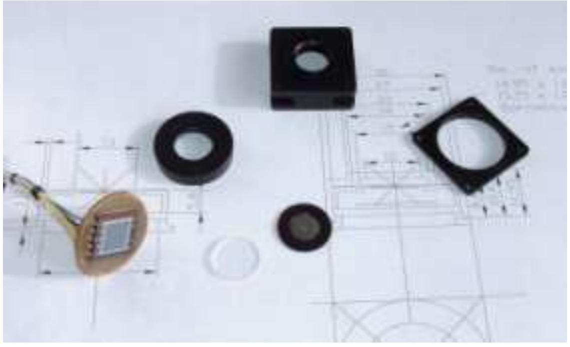
Transponder Frequencies: Inverting to reduce Doppler.

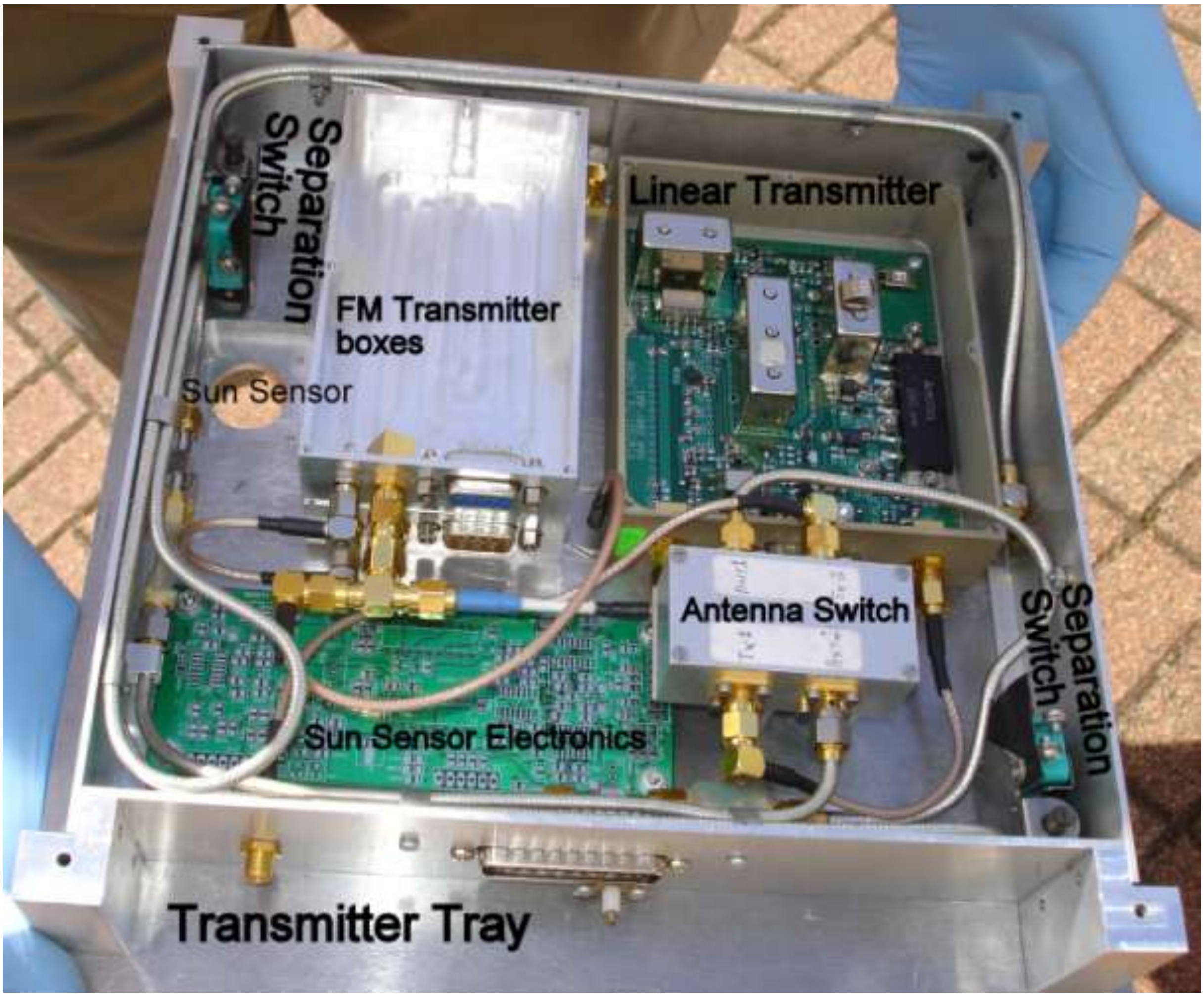
Uplink	435.260 to 435.230 MHz	1268.880 to 1268.850 MHz
Downlink	145.850 to 145.880 MHz	
Beacon	145.885 MHz	

Flight Sun Sensor Mk 2:

Two flown, one is on attic opposite to Horizon Sensor, second is mounted on -Z (bottom) target face.
The sensor consists of a Hamamatsu Position Sensitive Detector which has +- 45 degree field of view through a small hole in face of unit. 9 volt battery shows relative size of Sun Sensor.

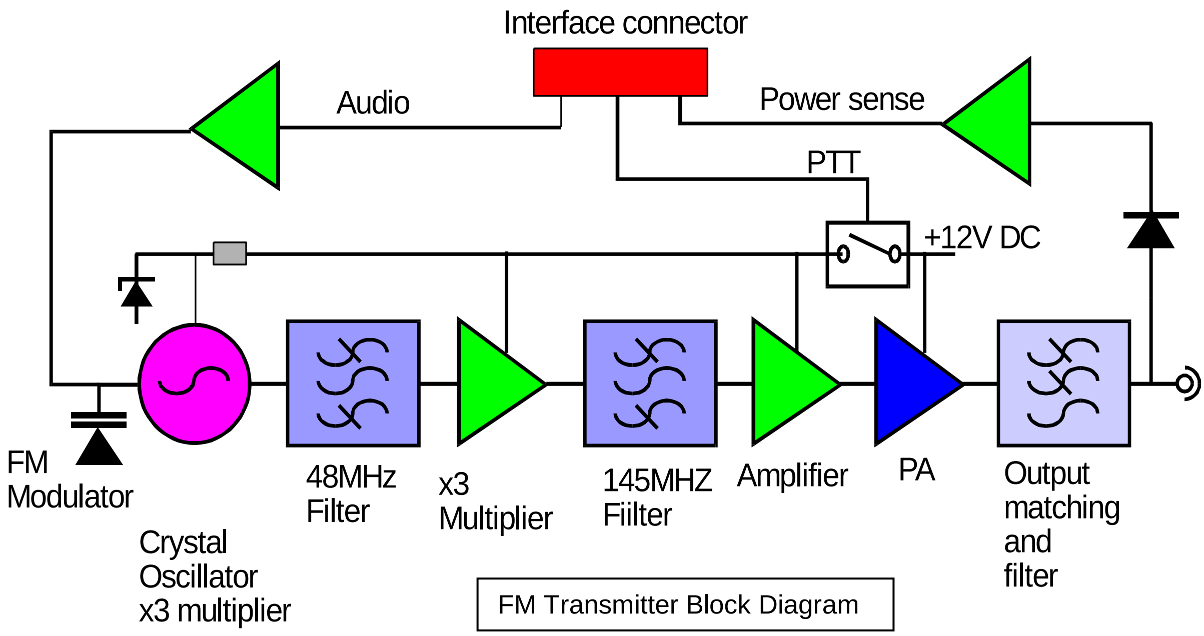
Size: 30mm sq. x 14mm deep. Weight: 20 gm.





The BCR, IHU and Battery Trays after first stage of CNC milling. Trays have 3mm excess metal still. Thanks to Mike Jack of Stanier Engineering for the CNC machining.

FM VHF 2 Watt Transmitter by Kelvin Barnsdale ZL3KB



FM Transmitter Block Diagram

Frequency: 145.865 MHz

Crystal frequency: 16.2072 MHz

Output power: 1W

Spurious outputs: -35dBc

DC input: 12V at 260mA

Modulation: FM up to +/-5kHz

Temp range: -20 to +60

Freq stability over temp range: +/- 10 ppm (1.4 kHz)

Audio input frequency: DC – 15 kHz (-3 dB)

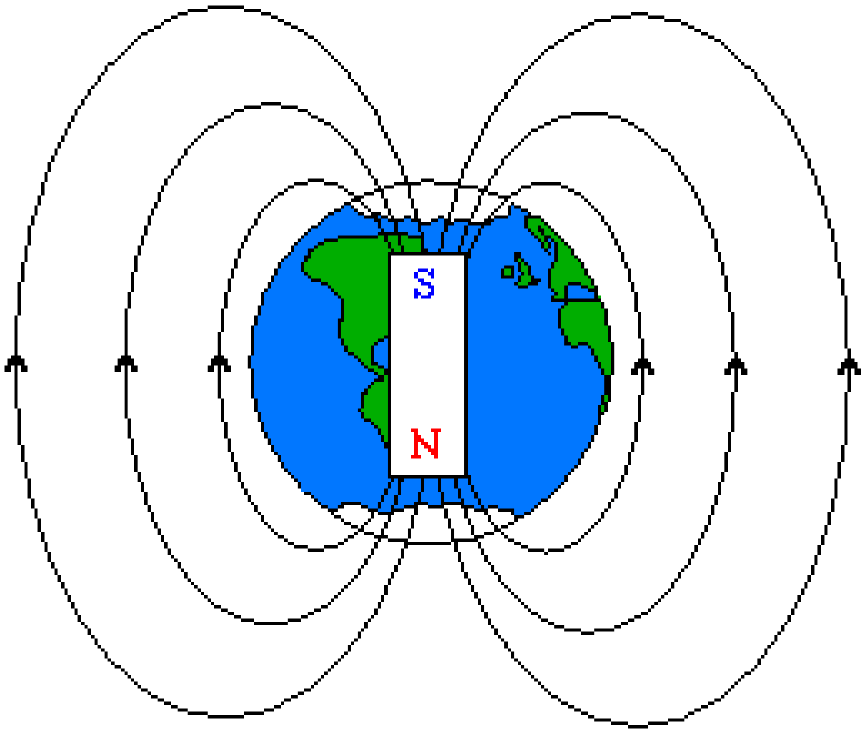
FM repeater mode:

Uplink	435.245 MHz
Downlink	145.865 MHz

Science Package (Attic or top layer)

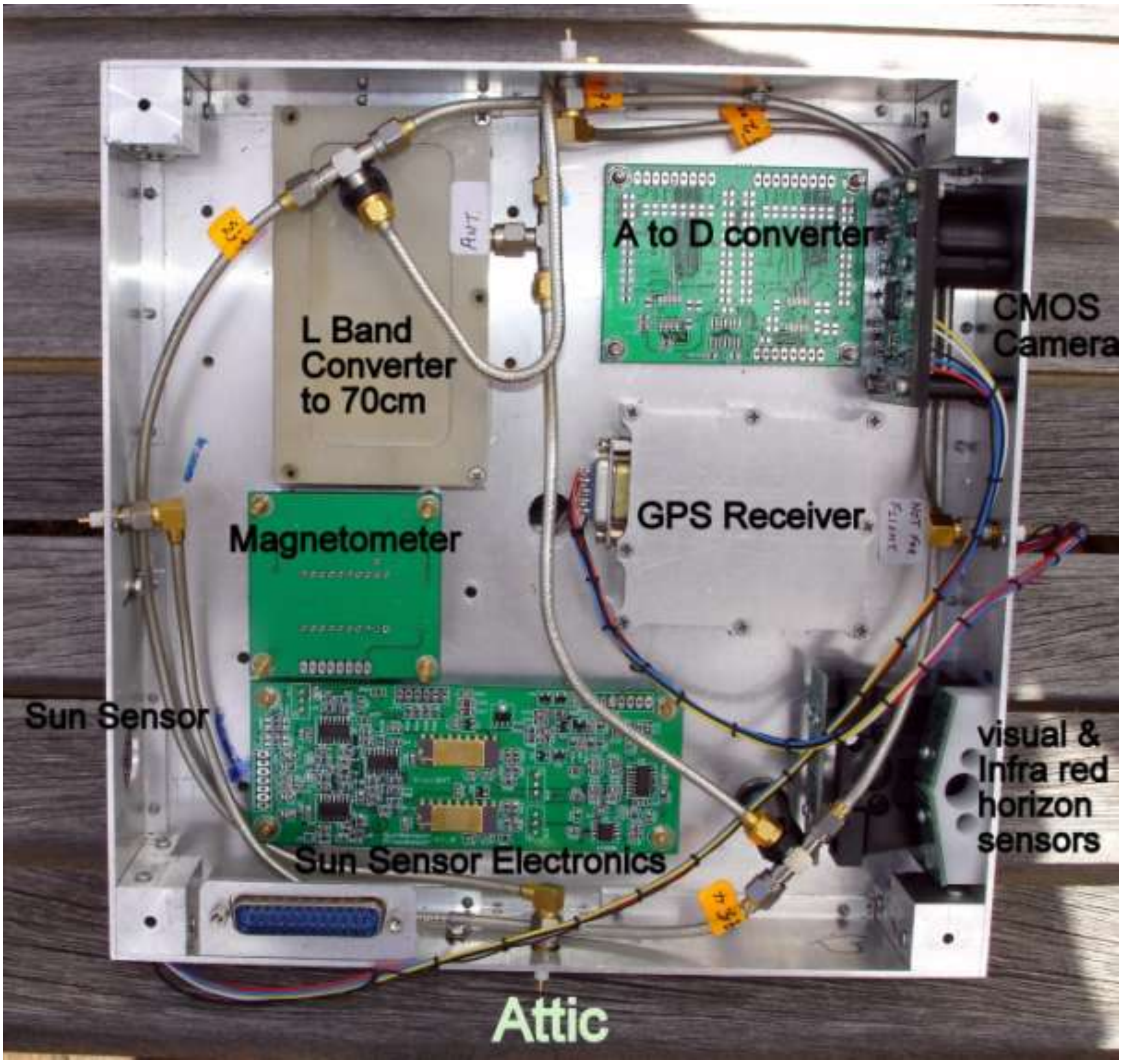
An Attitude Determination and Control (ADAC) system using the geomagnetic field.

A 3 axis 'air cored' coil system will be fitted with coils on X, Y and Z faces. These will be energized – as required – providing an active attitude control by interaction with the geomagnetic field.



X and Y coils for attitude control system on mock-up.

The Z axis coil is in the Battery Tray.

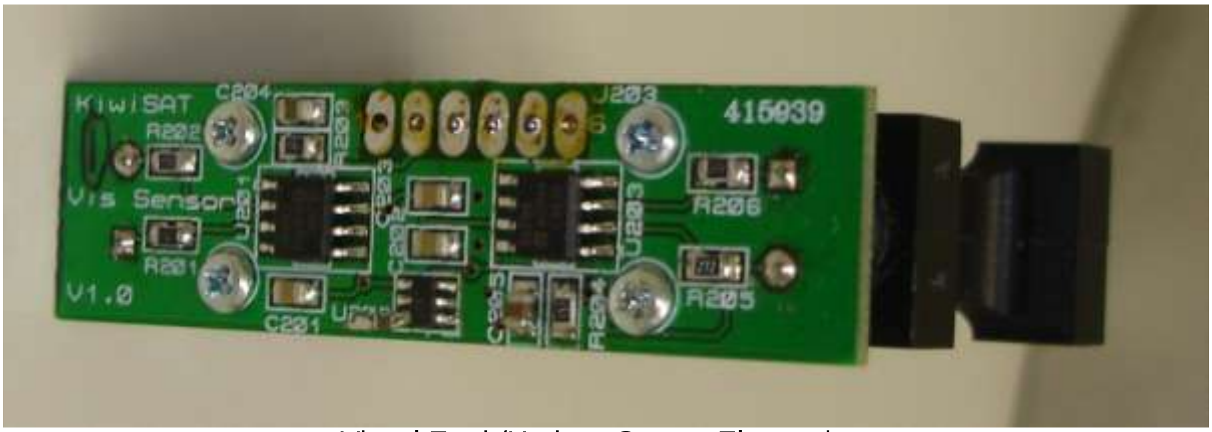


Science Package Attitude Determination Sensors:

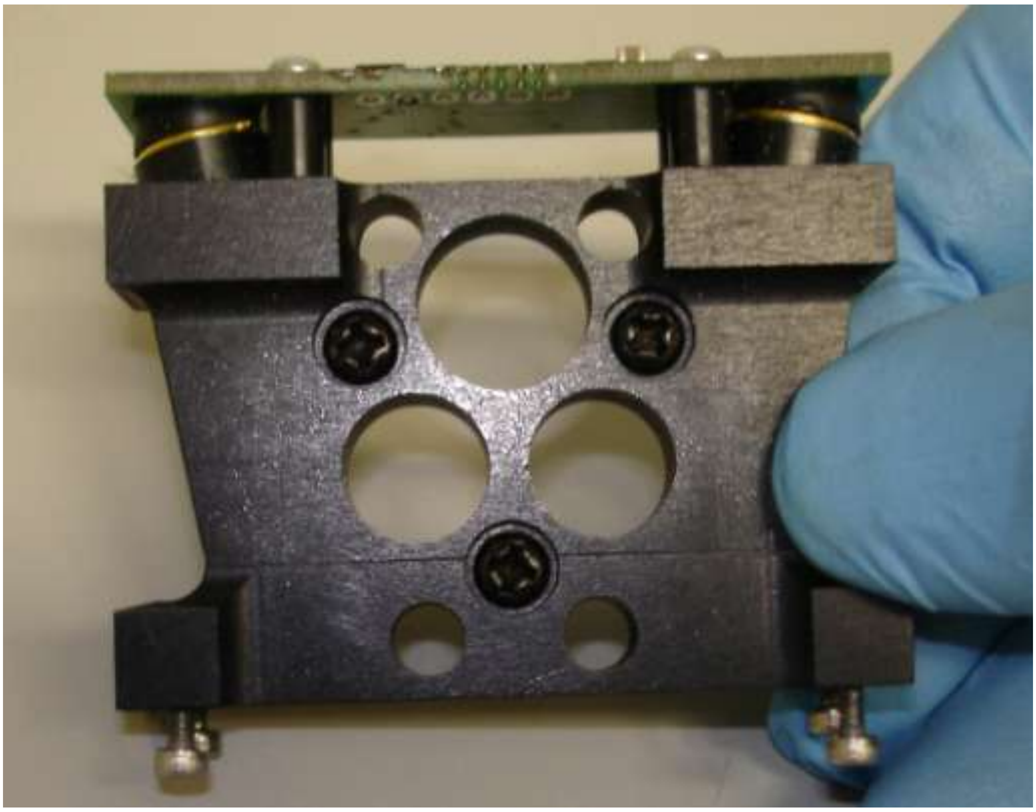
- Sun and Earth/Horizon sensors will provide reference information to 'fix' the satellites position/attitude in space.
- A 3 Axis Magnetometer will record/confirm attitude information using the earth's magnetic field.
- A suitable GPS receiver will fly for both positional and time data.
- A CMOS fixed focus camera to confirm the attitude calculated from sensor data will be flown.

Earth / Horizon Sensor:

- Part of Attitude Determination and Control fit
- Required to establish the X/Y Axis attitude in relation to the Earth
- System must eliminate any false responses direct from the Sun or any other light/heat sources.
- 2 Pairs photo-diodes - for visible and near infra red



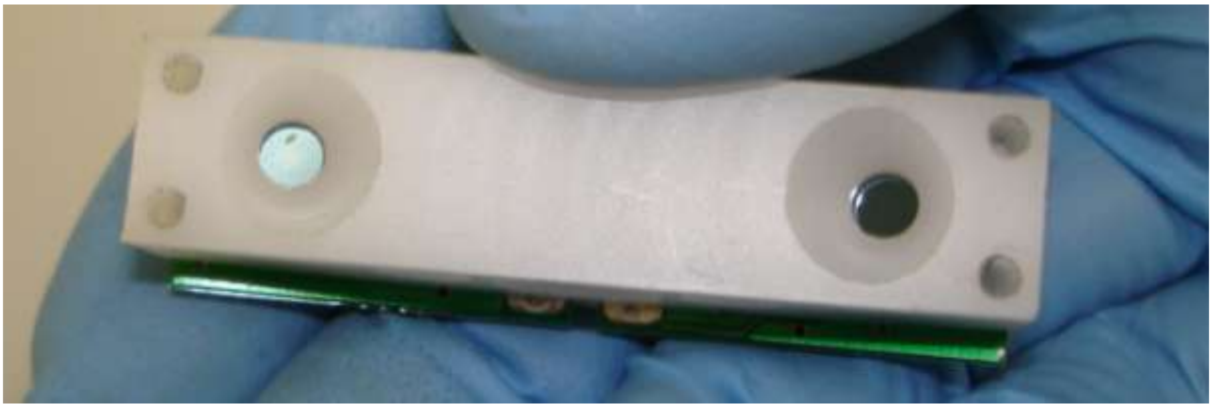
Visual Earth/Horizon Sensor Electronics



Visual Earth/Horizon Sensor

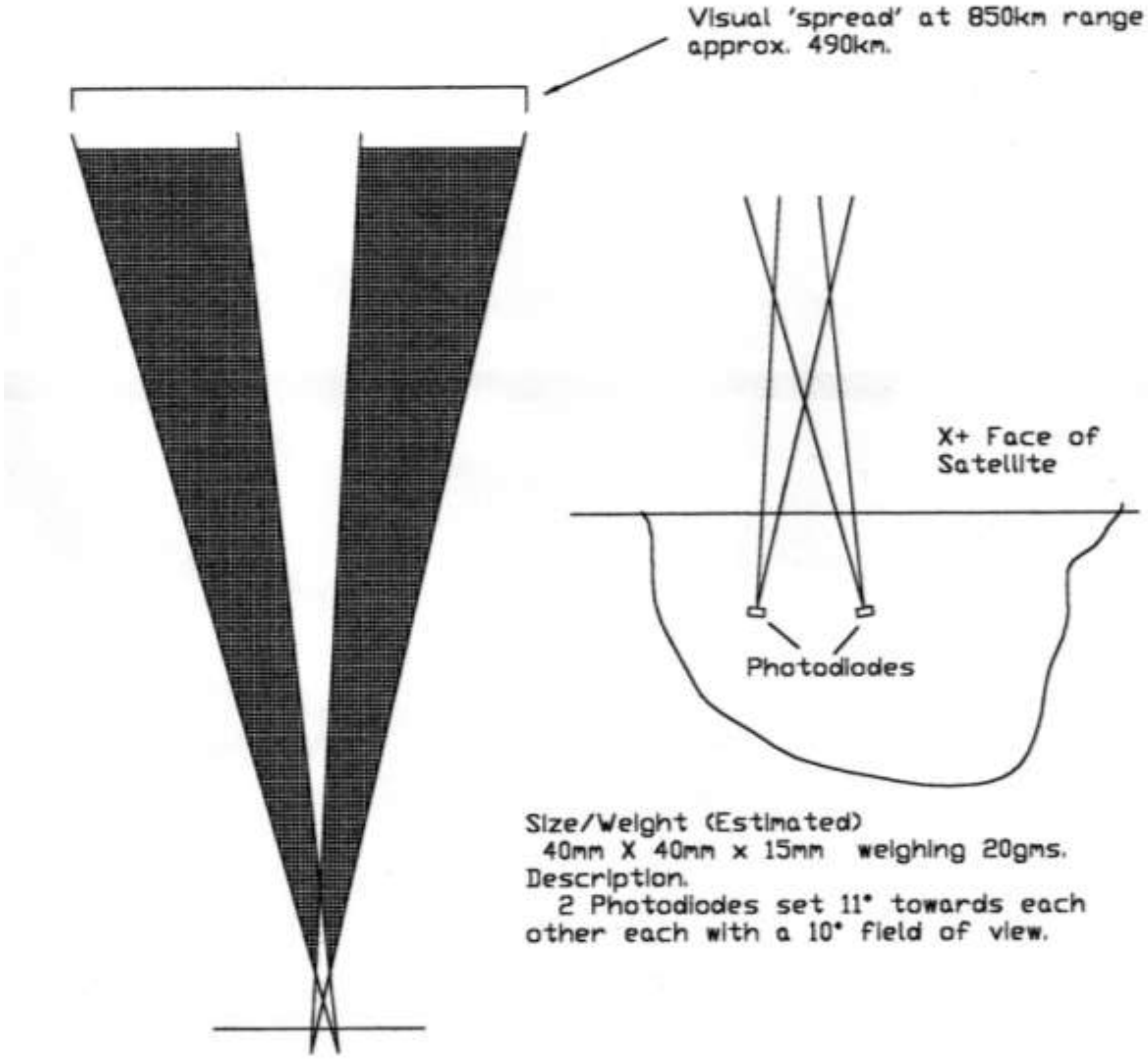
Based on system used on WeberSat. Light traps built into tunnels to stop reflections.

The Earth is only object large enough to be seen by both sensors at same time.



Infra Red Earth/Horizon Sensor

Earth Sensor Field of View

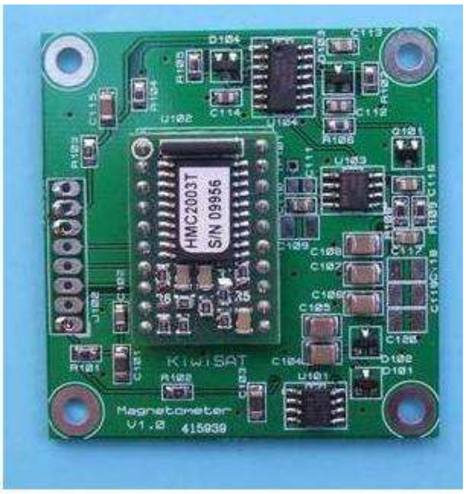


Magnetometer

Magnetometer Unit

A Honeywell HMC 2003 (3 axis) Magnetometer will be flown and this has been fitted on a PCB designed and built by Clayton (ZL3TKA) as shown on right. The magnetometer system – together with the reset facility – has been fully tested and is awaiting software and integration into the FlatSat.

A back-up unit is being built as a pre-flight spare.



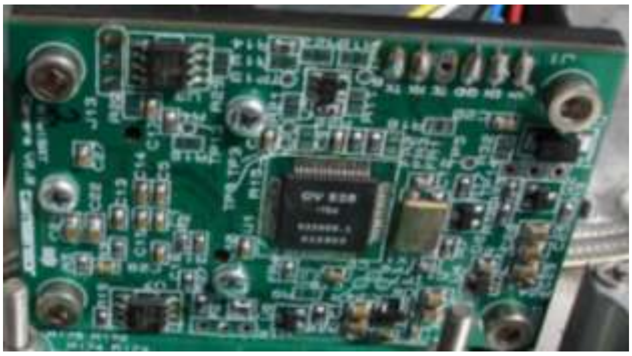
Magnetometer detector and circuitry - flight format.

CMOS Camera:

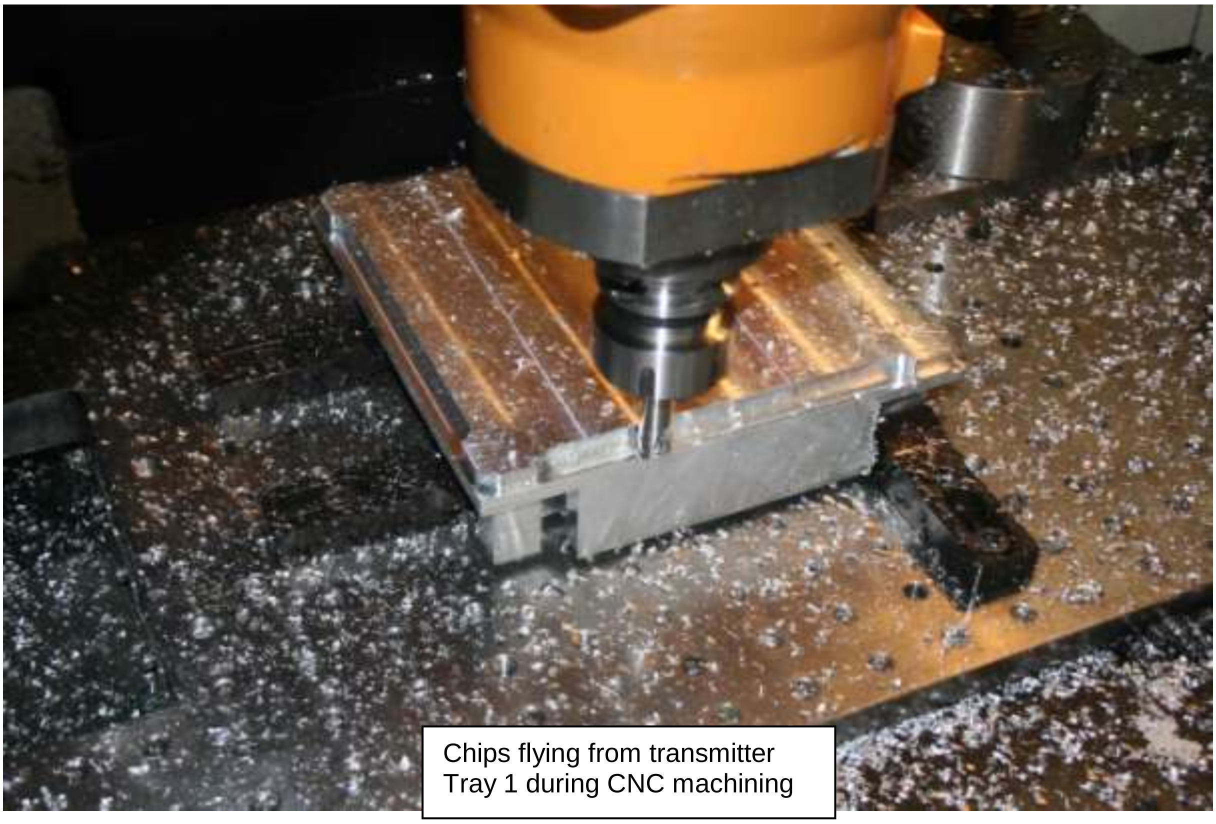
A small CMOS colour camera module has been located via the University of Tokyo.

Used on their first CubeSAT XI – IV

This camera will be used to confirm attitude of satellite.

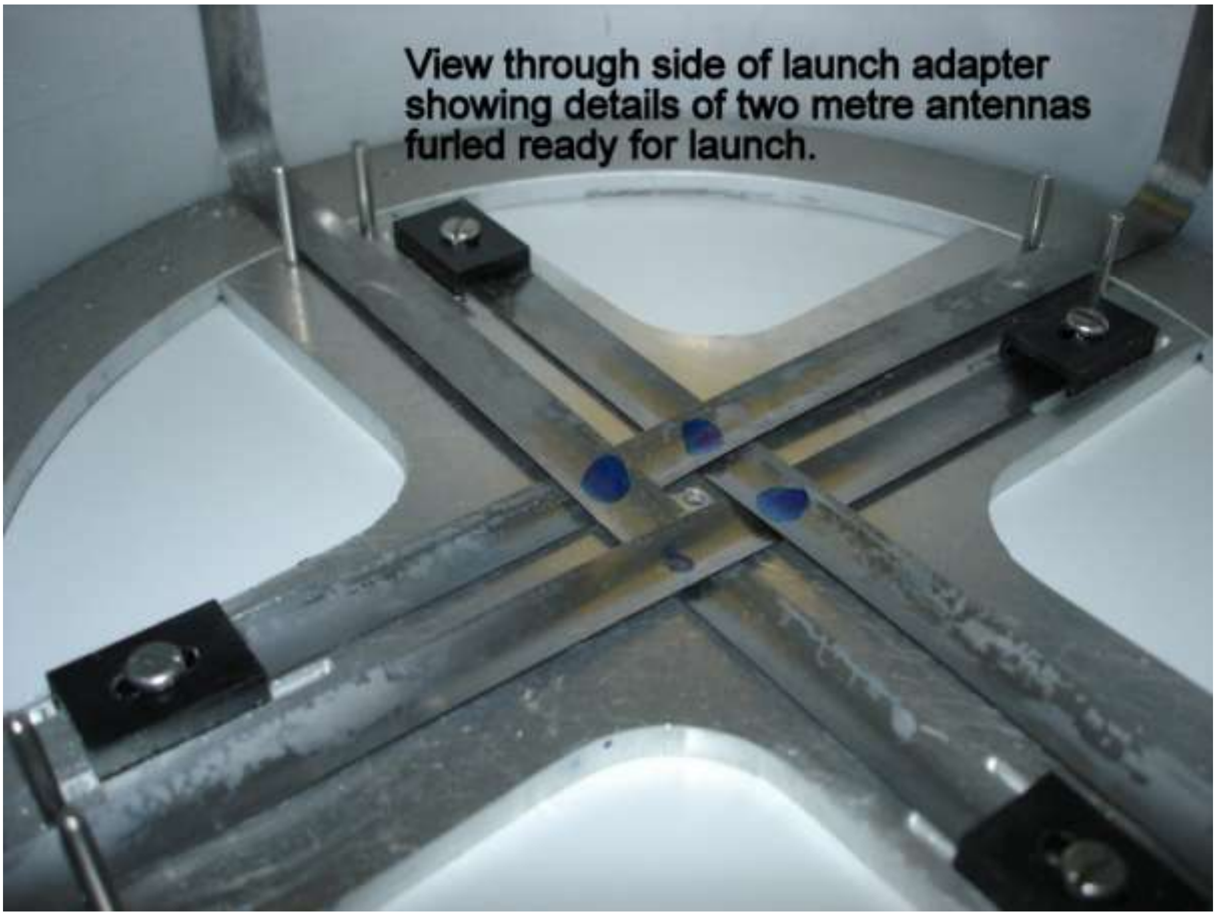


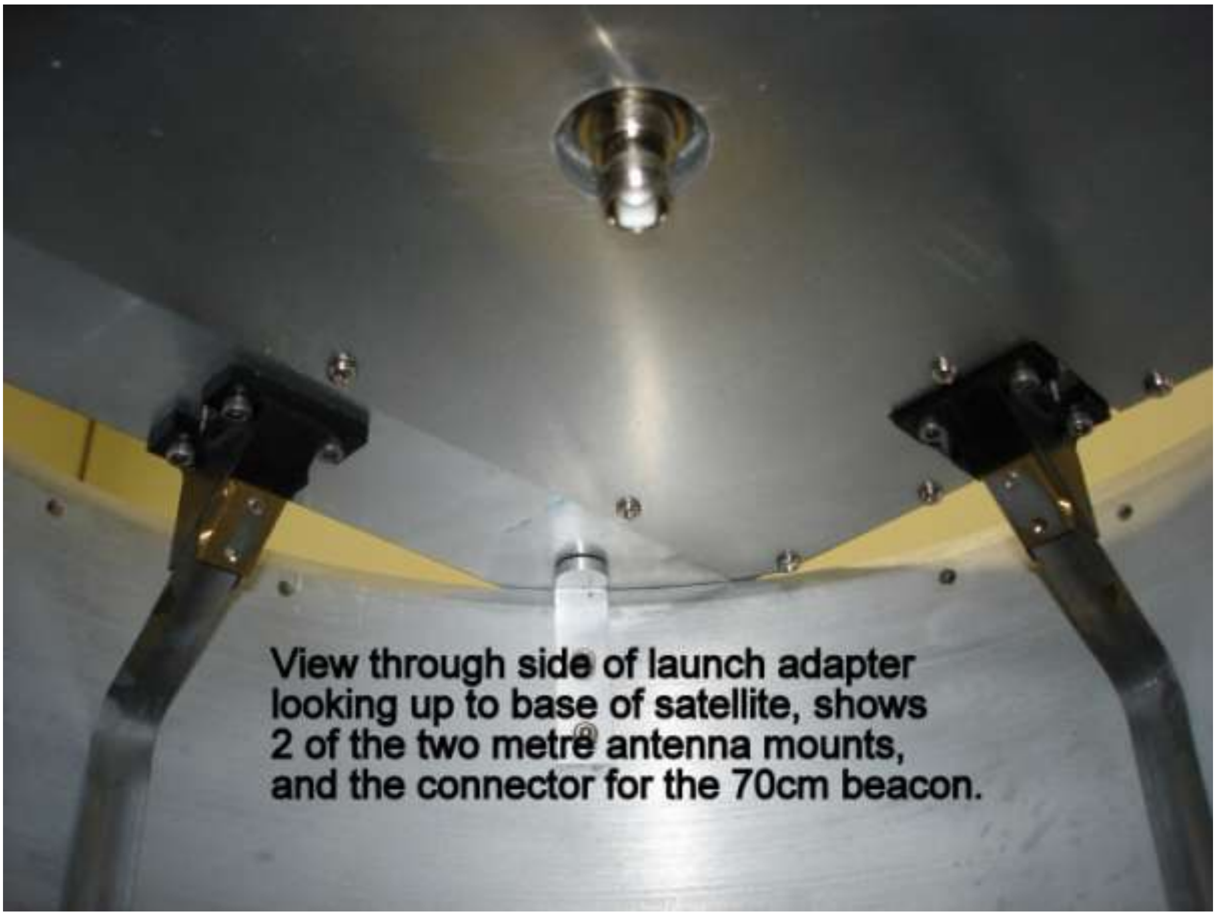
Designed and built by Clayton Gumbrell ZL3TKA

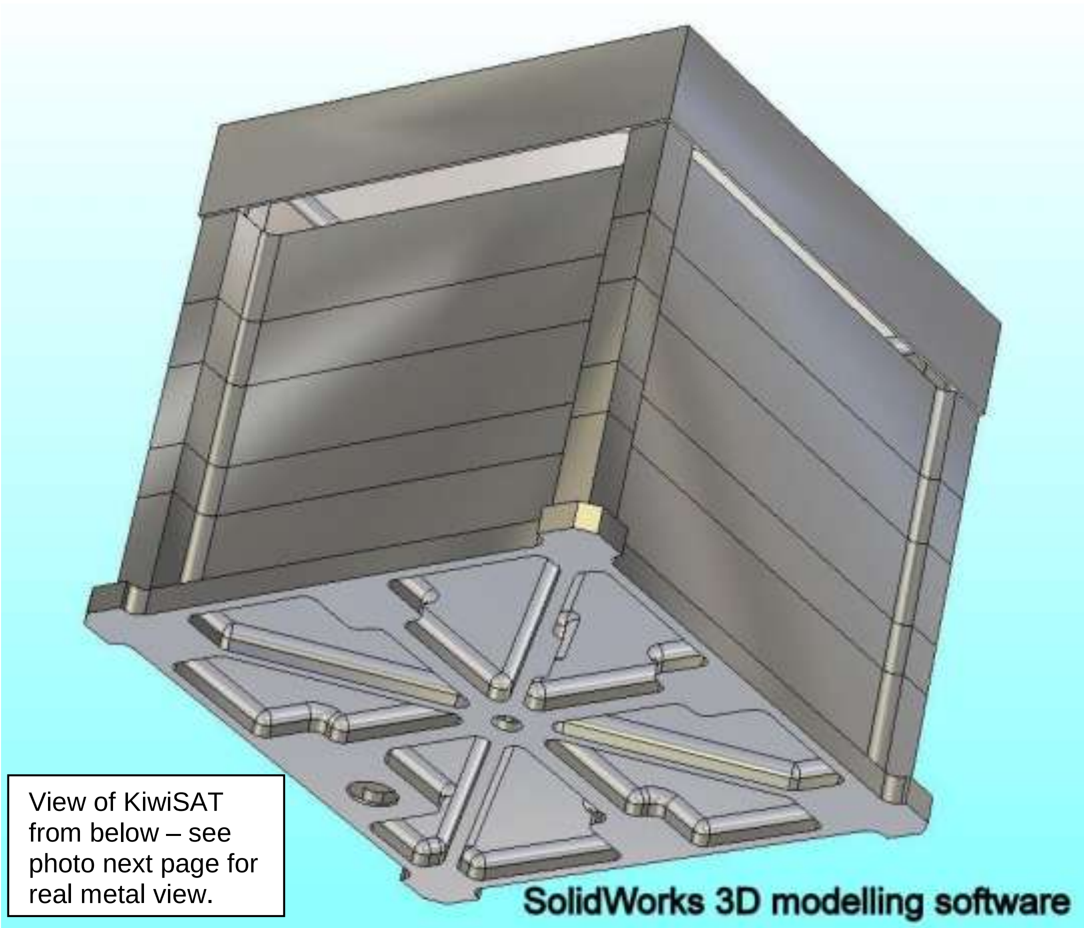


Chips flying from transmitter Tray 1 during CNC machining


Looking down into the Launch Adapter


View through side of launch adapter
showing details of two metre antennas
furled ready for launch.

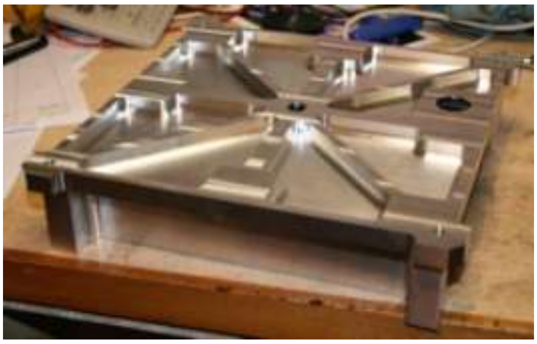




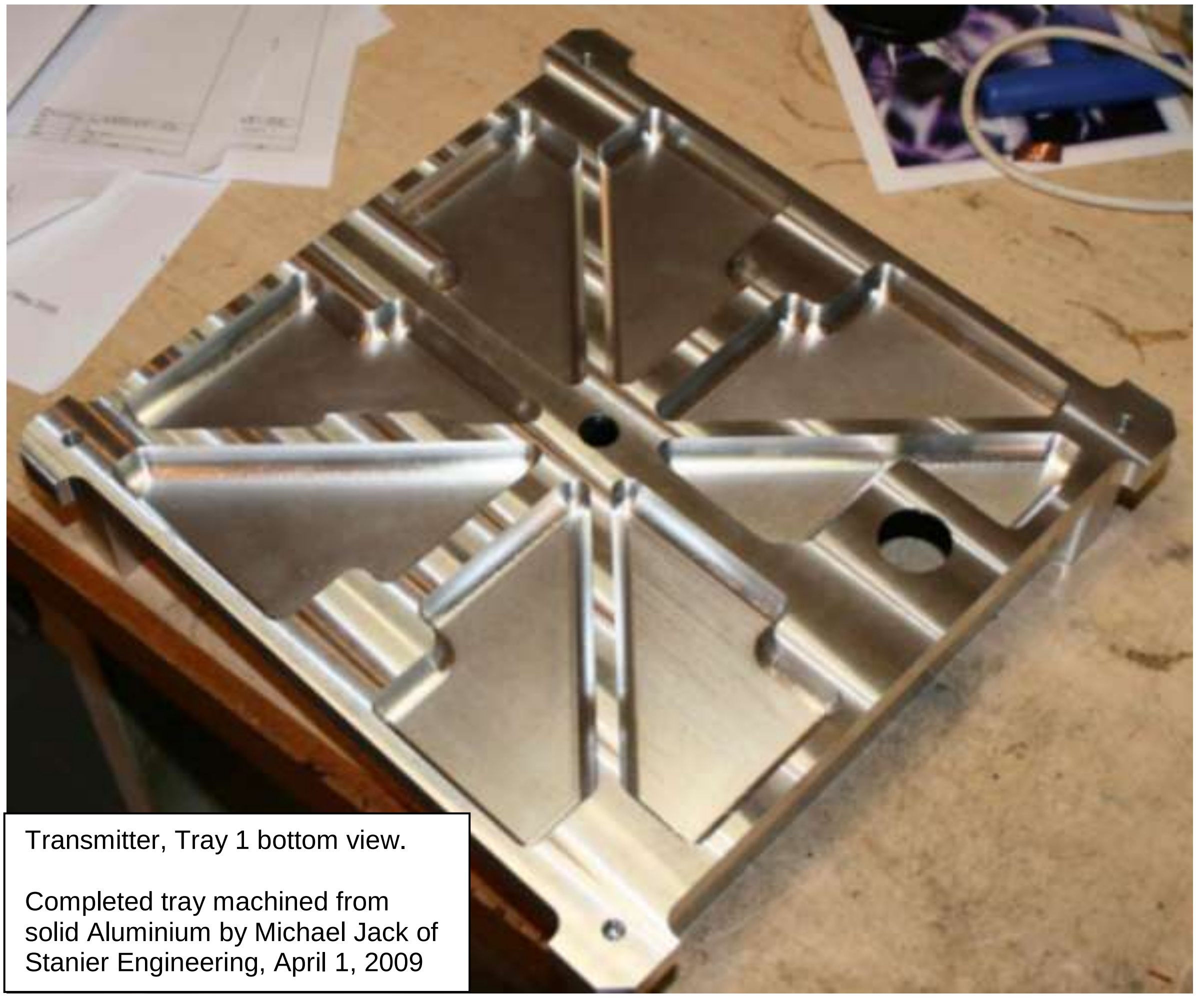
View of KiwiSAT from below – see photo next page for real metal view.

Thermal vacuum testing of Linear Transponder and IHU at Massey University, Albany Auckland

Refer to the website of AMSAT-ZL for updates on the progress of KiwiSAT. A link to YouTube will show the machining of the Transmit Tray pictured below.



Completed Transmitter Tray



Transmitter, Tray 1 bottom view.

Completed tray machined from solid Aluminium by Michael Jack of Stanier Engineering, April 1, 2009

Planned Operating Frequencies (Subject to licensing confirmation)

- **Linear Transponder Downlink** :
  Frequency: 145.850 MHz to 145.880 MHz.
  Output Power: 2 Watts PEP.
  Radiated Power: 2 Watts (+33dBm) EIRP PEP.
  Bandwidth: 30 KHz. Emission Type: Depends on Uplink: CW, SSB etc.
  Antenna pattern: Omni directional in all planes.
- **Linear Transponder Uplink 1** :
  Frequency: 435.260 MHz to 435.230 (Inverting Transponder).
  Bandwidth: 30 KHz.
  Noise temperature: 273 degrees K.
  Emission Type: typically CW, SSB.
  Antenna Pattern: Quarter wave whip on +Z face (Omni in X-Y plane, Null in +Z and -Z direction).
- **Linear Transponder Uplink 2** :
  Frequency: 1268.880 to 1268.850 (Inverting Transponder)
  Bandwidth: 30 KHz.
  Noise temperature: 273 degrees K.
  Emission Type: typically CW, SSB.
  Antenna Pattern: 4 Dipole array (Omni in X-Y plane, +3 dbi Gain in +Z and -Z direction).

- **FM and Data Transmitter** :
  Frequency: 145.865 MHz.
  Output Power: 1 Watt.
  Radiated Power: 1 Watt (+30dBm) EIRP.
  Bandwidth: 20 KHz.
  Emission Type: 9600 bps data (G3RUH Packet standard) Telemetry and Data (various modes) scheduled with FM Voice or 1200 bps AFSK packet telemetry.
  Antenna pattern: Omni directional in all planes.
- **FM Receiver Uplink 1**:
  Frequency: 435.245 MHz.
  Bandwidth: 20 KHz.
  Noise temperature: 273 degrees K.
  Emission Type: 9600 bps data, FM Voice,
  Antenna Pattern: Quarter wave whip on +Z face (Omni in X-Y plane, Null in +Z and -Z direction).

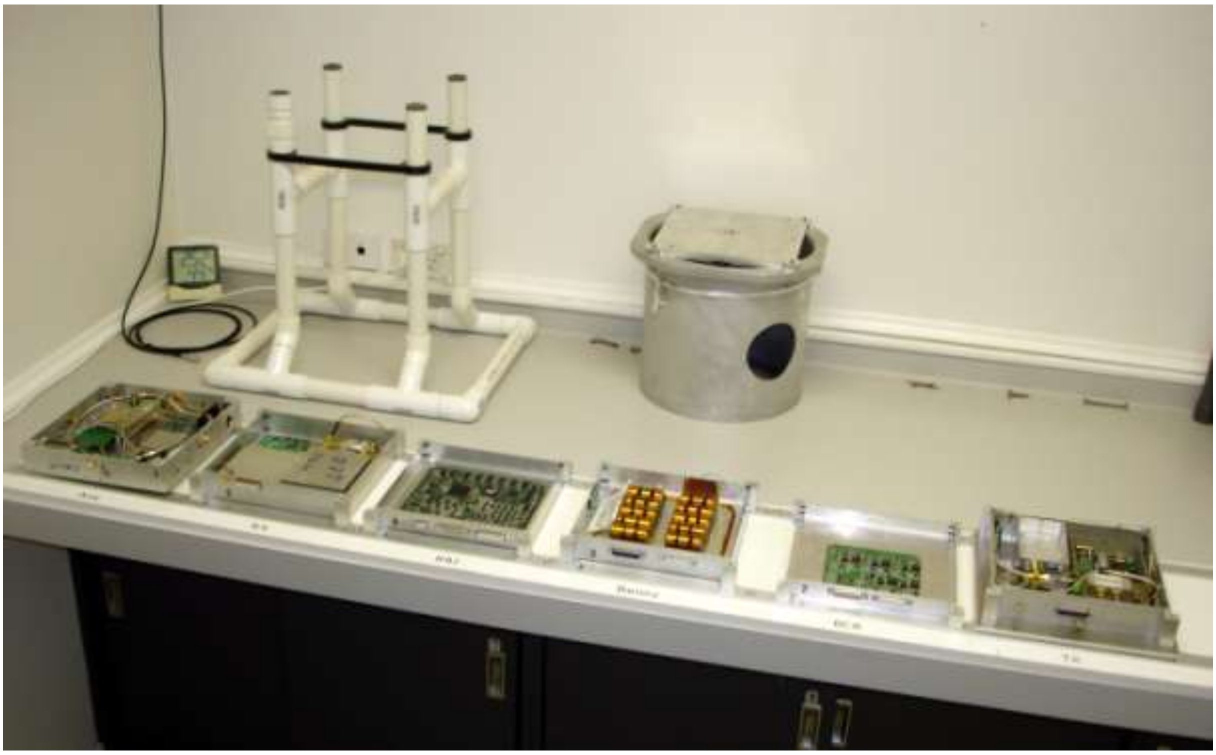
  FM Receiver Uplink 2:
  Frequency: 1268.865 MHz.
  Bandwidth: 20 KHz.
  Noise temperature: 273 degrees K.
  Emission Type: 9600 bps data, FM Voice,
  Antenna Pattern: 4 Dipole array (Omni in X-Y plane, +3 dbi Gain in +Z and -Z direction).

- **Beacons:**

Beacon 1:
CW Beacon Attached to Linear Transponder:
Frequency: 145.885 MHz.
Emission Type: CW standard Morse code.
Power: 50 mW (+17 dBm) EIRP

Beacon 2 (Data Beacon):
Frequency: 145.865 MHz.
Output Power: 1 Watt.
Radiated Power: 1 Watt (+30 dBm) EIRP.
Bandwidth: 20 KHz.
Emission Type: 9600 bps data (G3RUH Packet standard)
scheduled with 1200 bps AFSK packet telemetry.

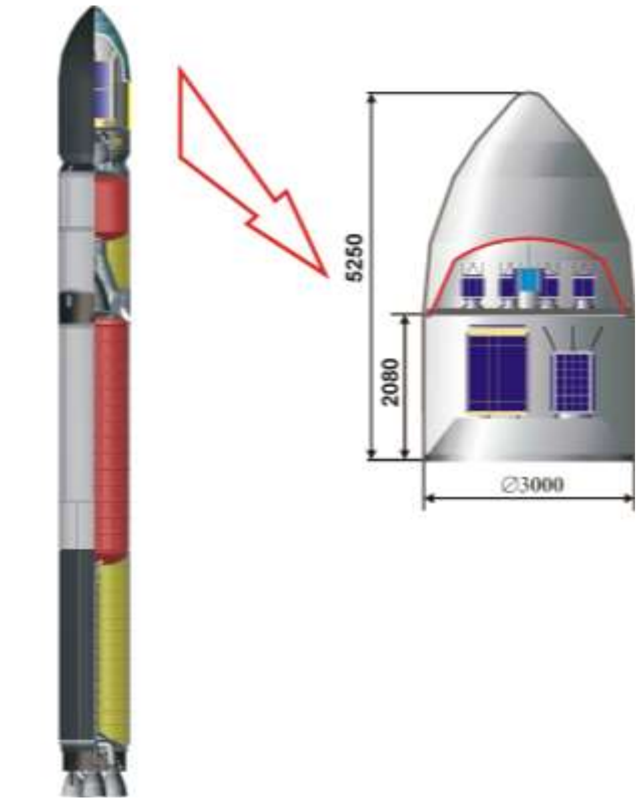
Beacon 3 (UHF Beacon):
Frequency: 437.425 MHz.
Bandwidth: 20 KHz.
Emission Type: 9600 bps data (G3RUH Packet standard).
Radiated Power: 100 mW (+20 dBm) EIRP.
Antenna pattern: Quarter wave whip on -Z face. (Omni in X-Y plane, Null in +Z and -Z direction).



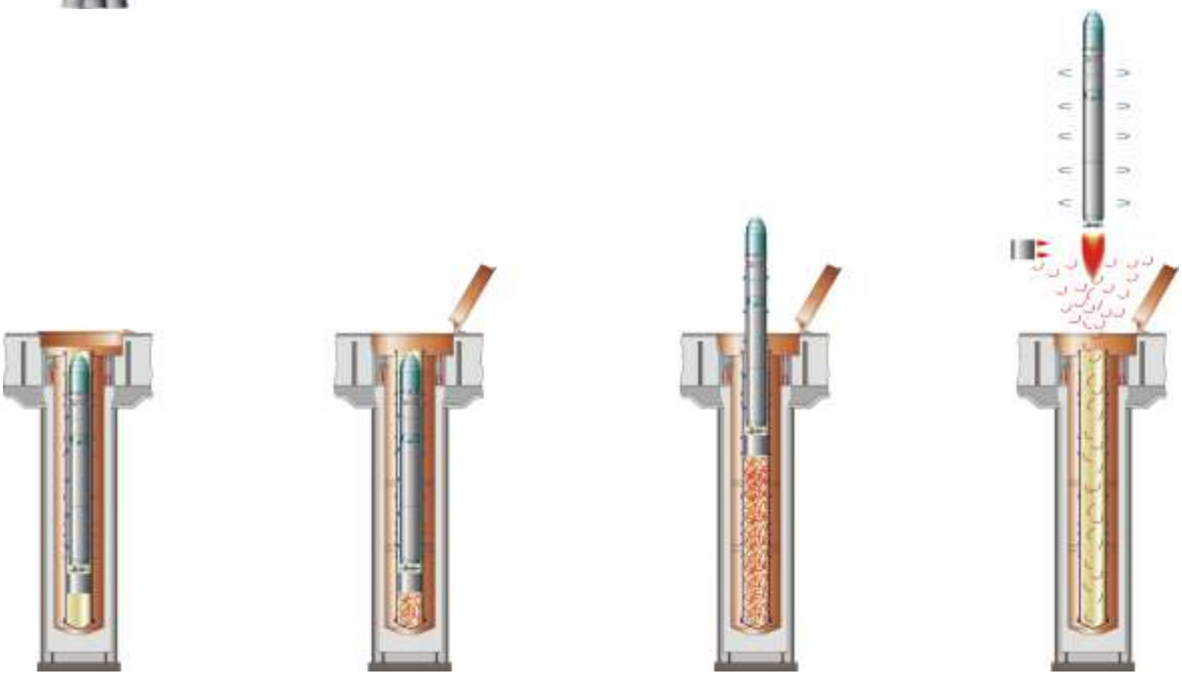
View of FlatSAT KiwiSAT in fabricated trays in the clean room at Massey University, Albany.

KiwiSAT – Launch proposals.

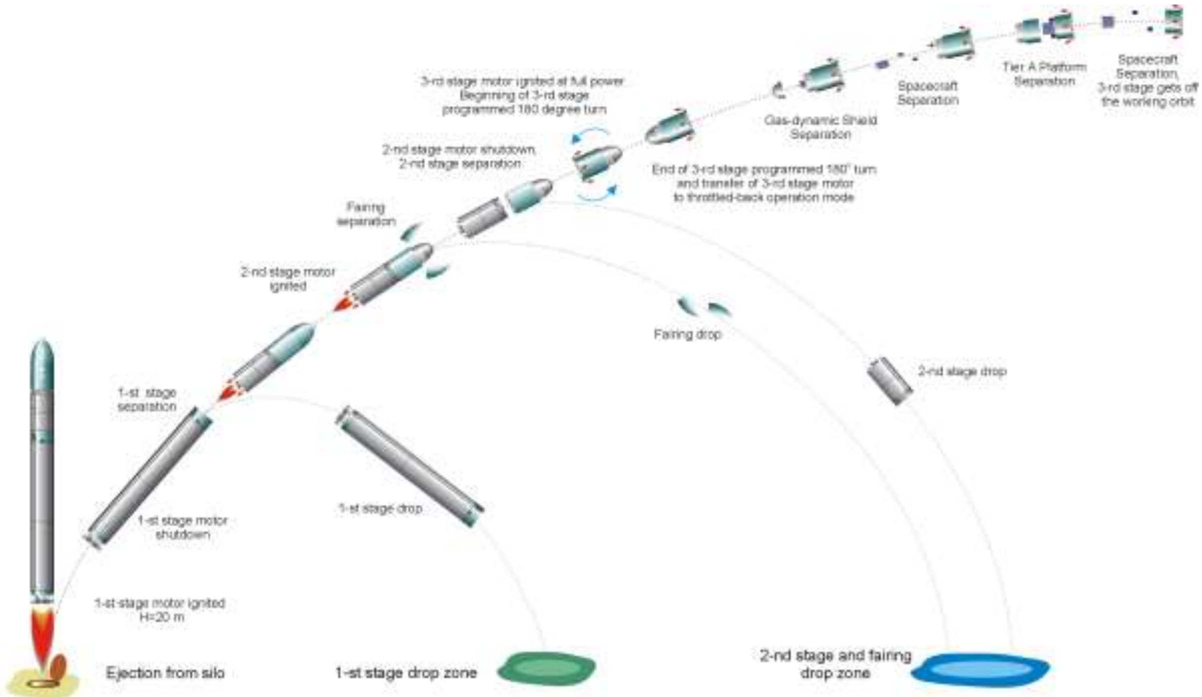
Russian DNEPR Space launch system



Standard Dnepr-1 Space Head Module configuration is arranged in double tiers, which enables multiple small spacecraft deployment capability (up to 10-15 small spacecraft).



This shows the initial launch of the Dnepr from its silo.



DNEPR Lift-off!

On the left is the first full scale model (11% cells) planned to fly with an ESA interface.

On the right is the planned version with the high efficiency (28%) solar cells and mounted on a cylindrical interface (sides cut away for demonstration purposes) to suit the Dnepr launch. Final version will have 22% efficiency solar cells as shown on page 8.

70 cm antenna on top and bottom (not visible), 23 cm dipoles mounted on the "attic" and the 2 m antennas folded into the mounting cylinder.

Present planning for KiwiSAT is to have a "FlatSAT" by May 2009. Details of the launch vehicle interface are being finalized and CNC controlled milling of the 6 trays from solid Aluminium plate has commenced, and final assembly of KiwiSAT can then be commenced.

Major fund raising or help from sponsors will be required for the launch program.

We would like to acknowledge the support of the Wellington VHF Group, Howick and Districts Radio Club and the Auckland VHF Group for major donations towards the KiwiSAT project. Many other individuals and companies have also provided generous support.