http://www.cubesatkit.com/

MAI-100 ADACS

Hardware Revision: n/a

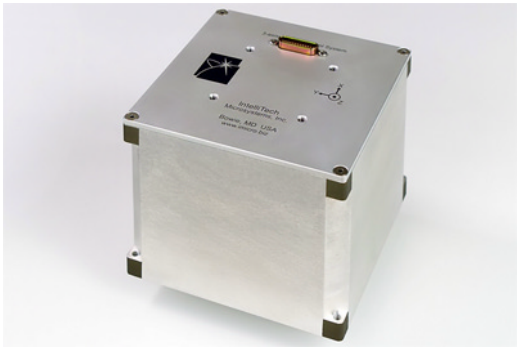
Miniature 3-Axis Reaction Wheel & Attitude Determination and Control System for CubeSat Kit™ Nanosatellites

Applications

- Imaging CubeSats
- CubeSats requiring accurate orientation in any direction (e.g. Sun, nadir, offset-nadir, ram, anti-ram, etc. orientations)

Features

- 1º pointing accuracy with supplied sensors, better than 1º with selected sensors
- Fully autonomous operation, with host spacecraft detumbling upon release and precise 3-axis attitude control thereafter
- 3 miniature reaction wheels
- 3 torque coils for momentum dumping and implementing B-dot law during detumbling
- Includes external 3-axis magnetometer
- 1.1 mNms momentum storage, each wheel
- 0.635 mNm maximum torque, each wheel
- Comprehensive command & telemetry via RS-232, single 25-pin miniature connector
- Low power (1.5W typ., <4.5 W max.), +12V single supply
- Low mass, 100 x 100 x 79 mm form factor
- Hermetically sealed, conductively plated
- Hard-anodized deployer contact surfaces



ORDERING INFORMATION

Pumpkin P/N 634-00412

Option Code	Configuration
/00 (standard)	with MAI magnetometer

Contact factory for availability of optional configurations.
Option code /00 shown.

CAUTION

Electrostatic Sensitive Devices

Handle with Care

The MAI-100 ADACS is a product of Maryland Aerospace, Inc (MAI)[1] and was developed by MAI for DARPA. This ADACS is a plug-and-play component of Pumpkin's CubeSat Kit family of nanosatellite components. It is supplied as part of the Pumpkin MAI-100 ADACS Kit (P/N 711-00416), which consists of the following items:

Qty	Pumpkin P/N	Description
1	634-00412	MAI-100 ADACS & external magnetometer
2	703-00398	CubeSat Kit Payload Adapter Plate
1	703-00397	CubeSat Kit ADACS Payload Walls
1	711-00408	CubeSat Kit ADACS Interface Module
1	709-00417	CubeSat Kit ADACS Software

[1] MAI changed its name in 2010 – it was formerly known as IntelliTech Microsystems, Inc. (IMI)

CHANGELOG

Rev.	Date	Author	Comments
F	20101111	AEK	Changed name references from IMI to MAI. Updated baud rate to 115,200 to reflect current firmware.
G	20110412	AEK	Minor update to specifications (including rad spec).

ABSOLUTE MAXIMUM RATINGS

Parameter	Symbol	Value	Units
Operating temperature	T_A	-40 to +80	ºC
Power Supply Voltage		+16	Vdc
RS-232 Input levels		-25 to +25	Vdc
Vibration		> 10	g rms

PHYSICAL CHARACTERISTICS

Parameter	Conditions / Notes	Symbol	Min	Typ	Max	Units
Width [2]	ADACS		99.9	100.0	100.1	mm
Depth [3]	ADACS		99.9	100.0	100.1	mm
Height	ADACS		78.70	78.74	78.78	mm
Mass	ADACS			865		g
Width	Magnetometer			28.7		mm
Depth	Magnetometer			28.7		mm
Height	Magnetometer			27.9		mm
Mass	Magnetometer			20		g

[2] For the body (i.e. the "box") of the ADACS. The ADACS lid edges are set back and measures 99.92 mm x 99.92 mm (w x d), and will not contact any portion of the CubeSat deployment mechanism (e.g. P-POD rails).
[3] Ditto.

OPERATIONAL CHARACTERISTICS

Parameter	Conditions / Notes	Symbol	Min	Typ	Max	Units
Service life [4]	LEO		1	5		year
Pointing accuracy	Using supplied magnetometer and basic sun sensor data				1	º
	Using additional sensors [5]				1-3	arcsec
System bandwidth				0.05		Hz
Slewing rate [6]	2U, 2kg CubeSat Kit, each axis				8.4	º/sec
Telemetry rate					5	Hz
Momentum storage	Per wheel				1.1	mNms
Torque	Per wheel				0.635	mNm
Radiation tolerance				30		krad

SERIAL INTERFACE

Parameter	Conditions / Notes	Value	Units
Baud rate		115,200	bps
Parity		none	
Data bits		8	bit
Stop bits		1	bit

ELECTRICAL CHARACTERISTICS

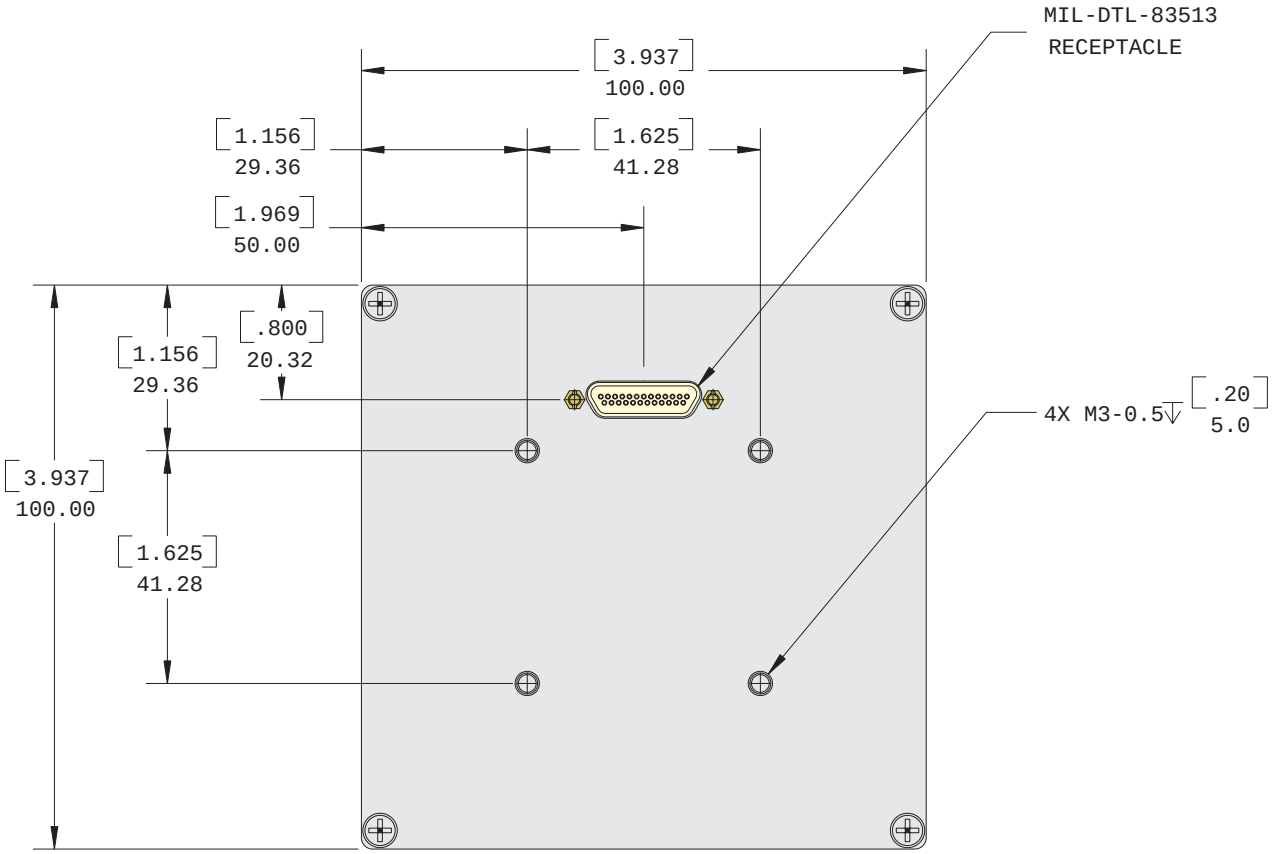
(T = 25ºC, +12V in = +12V unless otherwise noted)

Parameter	Conditions / Notes	Symbol	Min	Typ	Max	Units
Maximum supply current from +12V	3 motors running, 3 torque coils on continuously, 5Hz telemetry	I_{ON_MAX}		200	350	mA
Minimum supply current from +12V	All motors off, torque coils off, magnetometer on, 5Hz telemetry	I_{ON_MIN}			17	mA
RS-232 output levels			-7		+7	Vdc
Minimum supply voltage for motors	Motors operate at reduced torque capability	V_{MTR_MIN}	9			Vdc
Minimum supply voltage for electronics	ADACS electronics still functional	V_{ELEC_MIN}	7			Vdc

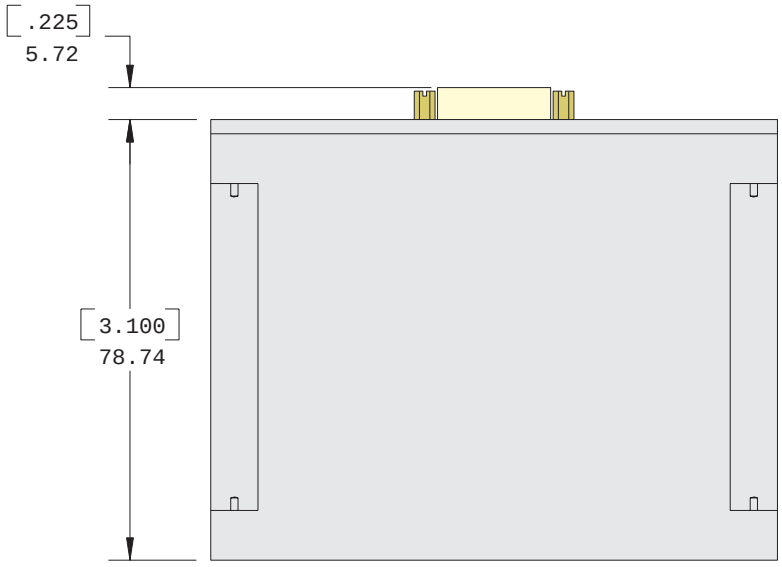
[4] Inferred. Not tested. Not guaranteed. Internal components are typical of 10Krad components. The construction of MAI-100 places a substantial amount of metal between the internal components and the outside world (in most directions). By request, component analysis can be performed for more demanding (e.g. GEO) orbits.
[5] Expected accuracy using a ring laser gyro and a miniature star tracker (not included).
[6] A larger ADACS, the MAI-200, features a maximum momentum storage of 11 mNms and can slew a 25 lb (11.4 kg) spacecraft at 5 deg/sec.

SIMPLIFIED MECHANICAL LAYOUT [7]

TOP VIEW



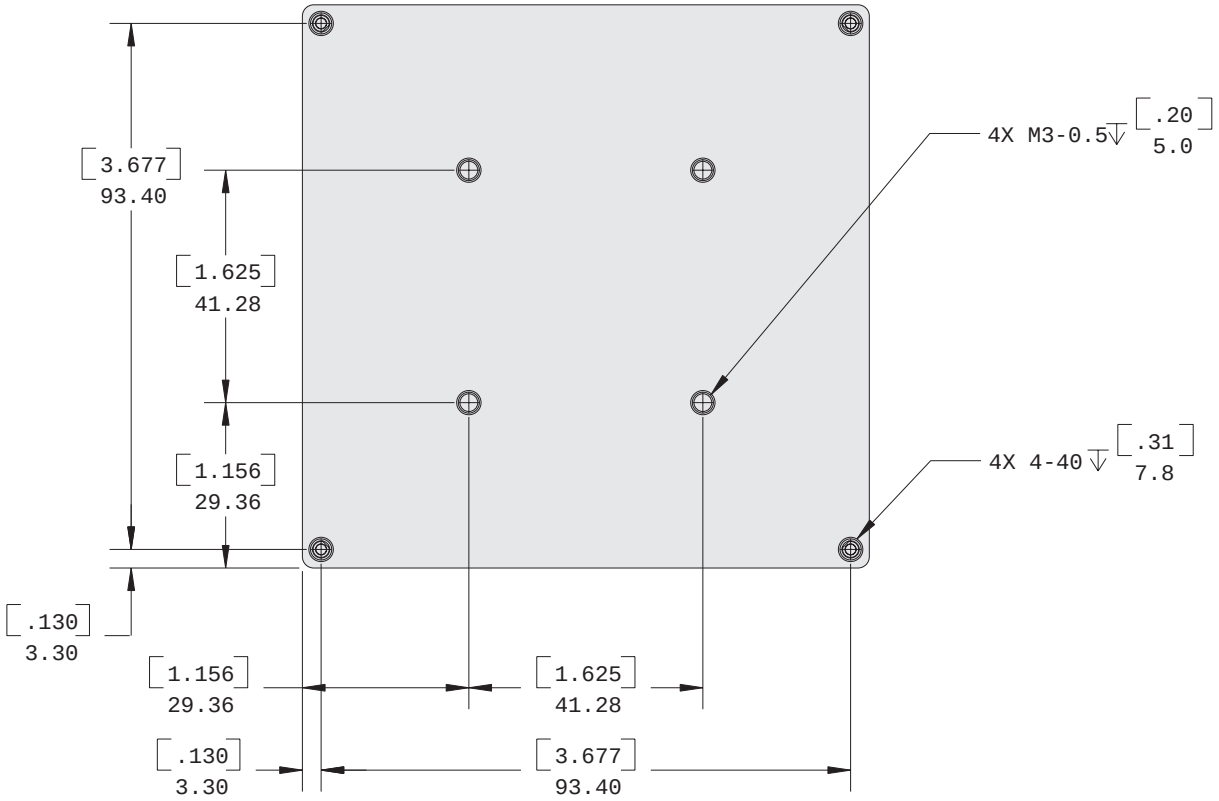
SIDE VIEW



[7] Dimensions in mm ([inches]).

SIMPLIFIED MECHANICAL LAYOUT (cont'd) [8]

BOTTOM VIEW



[8] Dimensions in mm ([inches]).

SEU SUSCEPTIBILITY

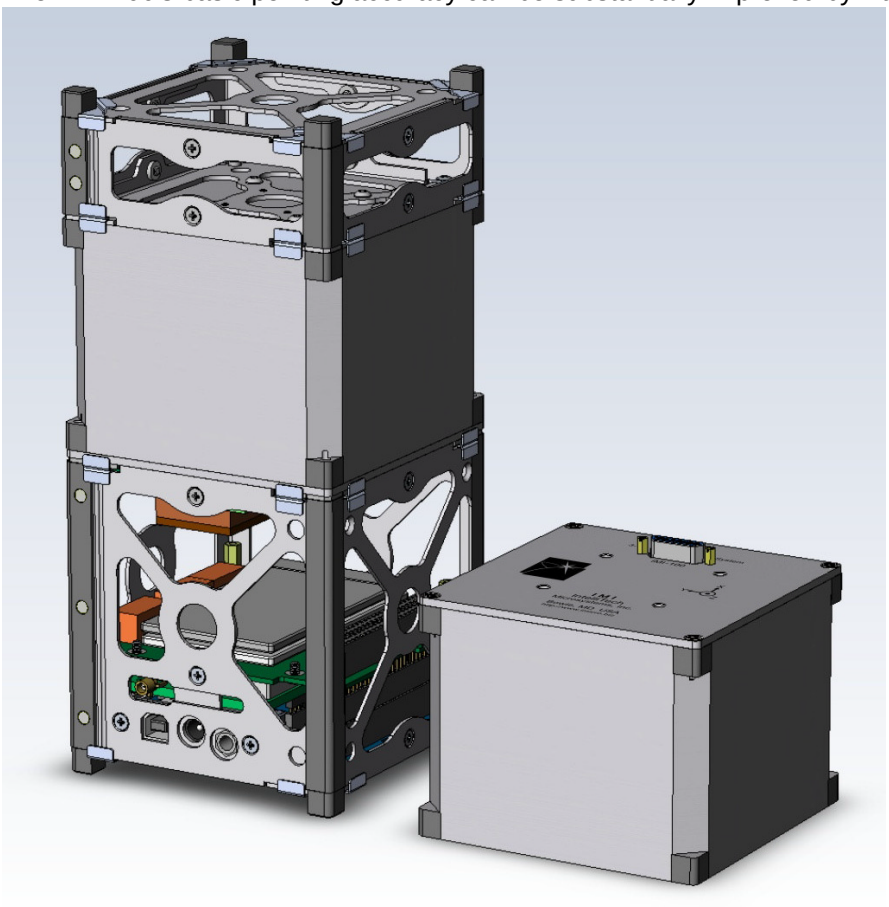
No analysis has been performed nor has any data been collected on the MAI-100's Single-Event Upset (SEU) susceptibility. It is not expected that an SEU would lead to destructive latchup. A complete reset (via external power cycling) can always be used to resolve SEU latchups.[9]

OPERATIONAL DESCRIPTION

The MAI-100 is an Attitude Determination and Control System (ADACS) that is designed to provide small spacecraft with highly accurate 3-axis pointing capability. It contains 3 reaction wheels, 3 torque coils and an ADACS computer, and works with an external magnetometer (supplied). A sun sensor can be provided, or it can use data or voltages from the customer's solar panels. Pointing accuracy is 1° with the supplied sensors. Higher accuracy (0.2° or better) is possible with external sensors.

The MAI-100 implements attitude control functions autonomously. The MAI-100 calculates spacecraft position from satellite orbital elements, the sun sensor and the magnetometer. If GPS is used, position information is given. The MAI-100 compares the measured earth magnetic field vector with the vector computed on-board from the satellite orbital parameters, computes the error between actual and commanded attitude, provides reaction wheel commands to minimize the error, provides momentum management using the torque coils, and maintains the commanded attitude accurately.

The MAI-100 is commanded from and provides telemetry to the host C&DH through its RS-232 interface. The MAI-100's basic pointing accuracy can be substantially improved by interfacing it to any one of a wide range of additional sensors (e.g. GPS, horizon sensor, star tracker, ring laser gyro) through its serial interface. Of course the requirements of every such sensor are unique. MAI can develop specific code to tailor each sensor to customer mission requirements.



2U CubeSat Kit nanosatellite (left) formed by combining 1U CubeSat Kit with MAI-100 ADACS Kit. Showing ADACS Payload Walls above and ADACS Interface Module with magnetometer below MAI-100. Two Payload Adapter Plates (upper one is visible at base of Payload Walls) attach the MAI-100 to the other CubeSat Kit structural elements. MAI-100 shown standalone (right).

Once on orbit, updated satellite orbital parameters can be input (i.e. uploaded) into the MAI-100's ADACS. Based on these parameters and time, the MAI-100 can compute the satellite's instantaneous position.

MAI will work with the end-user to tailor the ADACS software to the particular customer mission. The Mission Data Load preloads the orbital parameters into the MAI-100. These are updated (by the host C&DH) on orbit. While all attitude maneuvers are implemented autonomously from only the commanded attitude, specific 16-bit commands can also be given from the host C&DH. These include wheel speeds

[9] The CubeSat Kit ADACS Interface Module senses current drawn from the +5V supply to the 12V dc/dc converter that powers the MAI-100 and limits the current draw to a predetermined value. Additionally, a fault output is available.

(for pitch bias momentum stabilization), wheel torques, wheel angular displacements, and torque commands to the three 0.1 A-T-m² torque coils. Telemetry includes wheel speeds, torque coil activity, temperature, and pressure. The MAI-100 is also field reprogrammable by the end-user through the external connector.

For further detailed information on the MAI-100, refer to MAI document *MAI-100 ADACS Command / Telemetry / Interface ICD*, supplied with each MAI-100.

INTEGRATION INTO CUBESAT KIT FAMILY

The MAI-100 mounts to any CubeSat Kit Chassis Walls and any CubeSat Kit Payload Walls using the CubeSat Kit Payload Adapter Plate. The smallest possible CubeSat Kit configuration using an MAI-100 has a total length of 1.5U. 2U and 3U configurations are also possible. The MAI-100 can be located in the middle or at one end of a CubeSat Kit spacecraft. See the CubeSat Kit system chart for more information.

The CubeSat Kit ADACS Interface Module provides a plug-and-play means of connecting the MAI-100's serial interface to the CubeSat Kit Bus and a 5V-to-12V dc/dc converter to power the MAI-100. High-grade microminiature connectors are used between the Interface Module and the MAI-100. The CubeSat Kit ADACS Interface Module mounts directly to a CubeSat Kit Payload Adapter Plate.

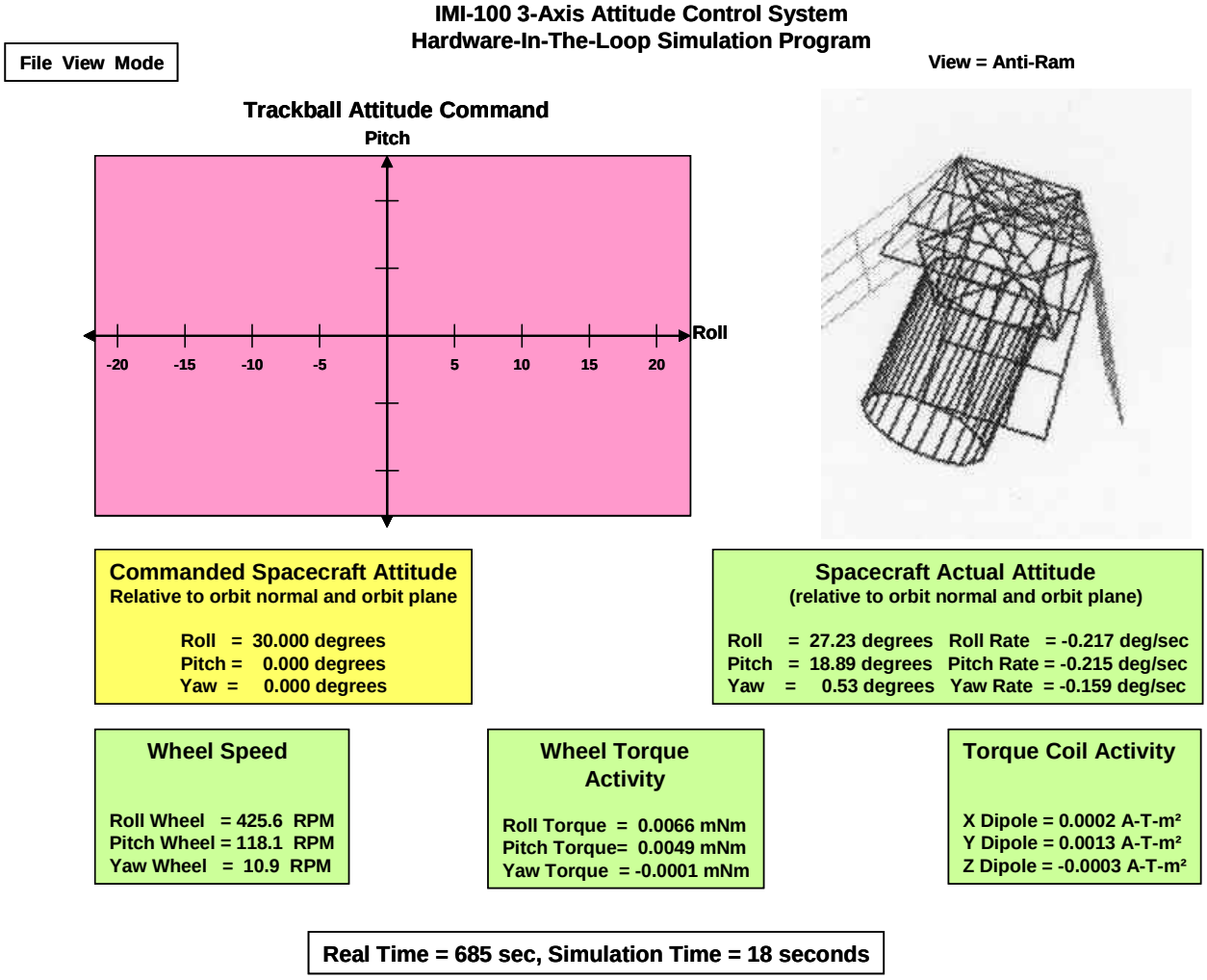
The MAI-100 is hermetically sealed, and fully occupies the 100mm x 100mm CubeSat cross-section. Therefore no wires or other components can pass through the MAI-100. Should there be a need to connect components below the MAI-100 to components above it,[10] the connector(s) should be routed through the available volume on the *sides* of the CubeSat Kit, alongside the sides of the MAI-100. Within this volume [11] – and subject to some limitations [12] – components up to 6.5mm thick can be located. Therefore discrete wires, cables, cable assemblies or even buried PCB layers (e.g. in PCB-based solar panels) can be used to route connections around the MAI-100.

[10] E.g. when the MAI-100 is in the center of a CubeSat Kit and a variety of sensors are placed at the end of the CubeSat Kit opposite from the end occupied by the C&DH, EPS, etc.
[11] In cross-section, this volume measures 6.5mm x 82mm x length(1.5U/2U/3U).
[12] See the CubeSat specification at http://www.cubesat.org/.

MAI TEST SOFTWARE

Test software is provided for embedding the MAI-100 ADACS into a Hardware-In-The-Loop (HITL) simulation program which simulates the performance of the ADACS in the target spacecraft**.** An illustration of the EGSE display is shown on the next page.

Software development can be undertaken with the aid of the dynamic simulator HITL environment which consists of a high fidelity software model of the spacecraft dynamics which runs in realtime on a PC. The MAI-100 is connected to the PC through a serial link which makes it appear to be the actual spacecraft. By constructing and running different operational scenarios, the flight software can be debugged, validated and verified for each specific mission.



FOR MORE INFORMATION

Contact Pumpkin, Inc. for pricing, purchasing and general inquiries.

Contact Maryland Aerospace, Inc. for programming, operational, sensor interface and mission-specific orbital inquiries, at

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EXPORT RESTRICTIONS

The United States government has determined that the MAI-100 is controlled by 22 CFR 121.1, Category XV (ITAR). Sales to customers outside the United States must conform to United States export regulations.

SPECIAL COPYRIGHT NOTICE

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- Salvo™ and the Salvo logo
- CubeSat Kit™ and the CubeSat Kit logo

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