UPAGRAHA

A SWARM ROBOTIC NANO SATELLITE

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Table of Contents

ABSTRACT

Are we alone in this universe? This question has troubled and baffled astronomers even before the primitive telescopes were invented. The sheer magnanimity of the solar system and the extent to which we can see often leaves us with the answer that there has to be some sort of life form somewhere else given the size of the universe.

Upagraha* is a complex system of multiple cubesat's that are designed to work together to explore the icy surfaces of Europa. Europa is the most likely place to find life in our solar system because we believe there exists an ocean of water beneath the thick sheaths of ice on the surface. We know on Earth that wherever there is water, we find life. All previous spacecraft's were designed to orbit Europa, but due to the high radiation surrounding Europa, any satellites that that stayed too long was eventually pronounced dead. The Hubble space telescope provides images of huge plumes of water erupting from the surface of Europa. If that is true, we can fly through those plumes and the Upagraha can literally taste it to understand the composition of Europa's interior and eventually answer the question if Europa harbors any sort of life form.

Upagraha is a swarm robotic nanosatellite that is designed to land on the surface of Europa and perform tasks such as multi-spectral imaging of the terrain, ice penetrating radar, ice-sample collection, sonar, and a variety of sensing instruments such as spectroscopes, magnetometers, and anemometers.

*Upagraha in Sanskrit means Satellite

DETAILED DESCRIPTION

The Upagraha consists of many nanosatellelites working together in unison to work on various aspects of understanding the topography, climate and elements that constitute the formation of Europa's structure. At the heart of every Upagraha lies an Atmega 2560 microcontroller that is used to acquire data inputs from the variety of sensors and also for navigating around the surfaces of Europa. The controller offers enough performance needed to implement a fully

functional swarm robotic nanosatellite while consuming low power. It offers 54 IO of which 15 can be used for PWM outputs, 16 analog pins, and a 16MHz inbuilt oscillator.

Every nanosatellite will be designed to perform specific tasks and coordinate with each other and provide specific information to the base station. Each of these Upgraha's comes with a wireless charging module. Each Upagraha flies back to the nearest battery station to charge once the battery level reaches 20%.

U: Weather

This Upagraha uses the "weather shield" from sparkfun. This sensor uses two lines of I^2C for communication. The sensors and their specifications are as follows:

- Humidity sensor, HTU21D, 3x3x0.9mm foot print.
- Barometric Pressure sensor, MPL3115A2, 5x3x1.1mm foot print.
- Light sensor, ALSPT19, 1.8x0.7x0.6 mm foot print.
- The RJ11 connector spaces are used for optional hook up of GP635T GPS module

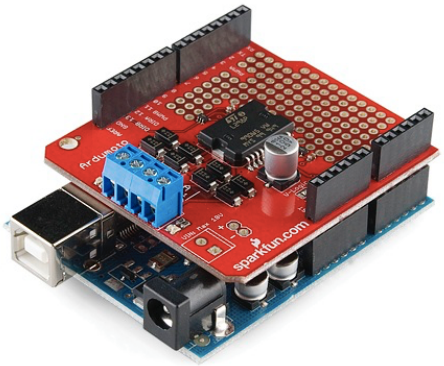

Figure 1, Weather Shield integrated to an Arduino Uno *(Source: https://www.sparkfun.com/products/12081)*

U: Ice Probe

This Upagraha uses a nuclear heated torpedo to melt and penetrate into the ice. Unlike the conventional drilling equipment, the torpedo uses lesser power and does not pollute the environment. Small quantitates of Uranium-235 readily absorb a neutron to become highly unstable isotope U-236. U-236 has a high probability of fission. This fission reaction is enough to melt the icy surfaces of Europa and penetrate the ice due to gravity.

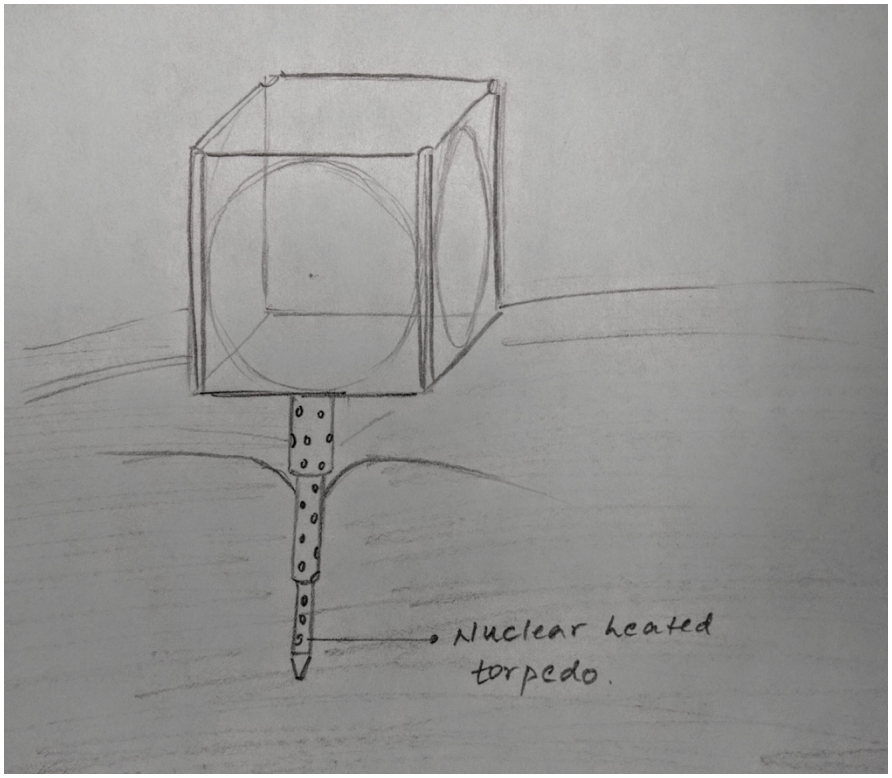

Figure 2, Ice Penetrating, Nuclear Heated Torpedo. (Artist's imagination)

U: Landers and Chargers

This Upagraha is mainly used to land the stacked nanosatellites safely onto the surface of Europa. These Upagraha's use Ambipolar thrusters. This uses a new design for permanent magnet helicon generated plasma thruster. The source is powered by a novel DC to RF oscillator with air-core inductors. Low gas flow rates (~4sccm) and high pumping speeds (~10,000 l/s) are used. Electrons heated by helicon wave → they rush out of the nozzle → slow ions dragged along by E field → electrons lose thermal energy to ion kinetic energy → higher electron temperature leads to higher ion velocity. Apart from functioning as a thruster to land the Upagrahas safely on Europa they come with a Radioisotope thermo electric generator (RTG). The RTG is an electrical generator that uses an array of thermocouples to convert heat released due to decay. This generator has no moving parts. The power output is connected to an inductive charging coil of 5V @ 500mA. These Upagraha's have a GPS module so that all other Upagrahas can come and dock themselves for charging. The GPS module used is a SparkFun GPS shield. The DLINE/UART switch switches the module's input/output between the arduino's Tx/Rx pins.

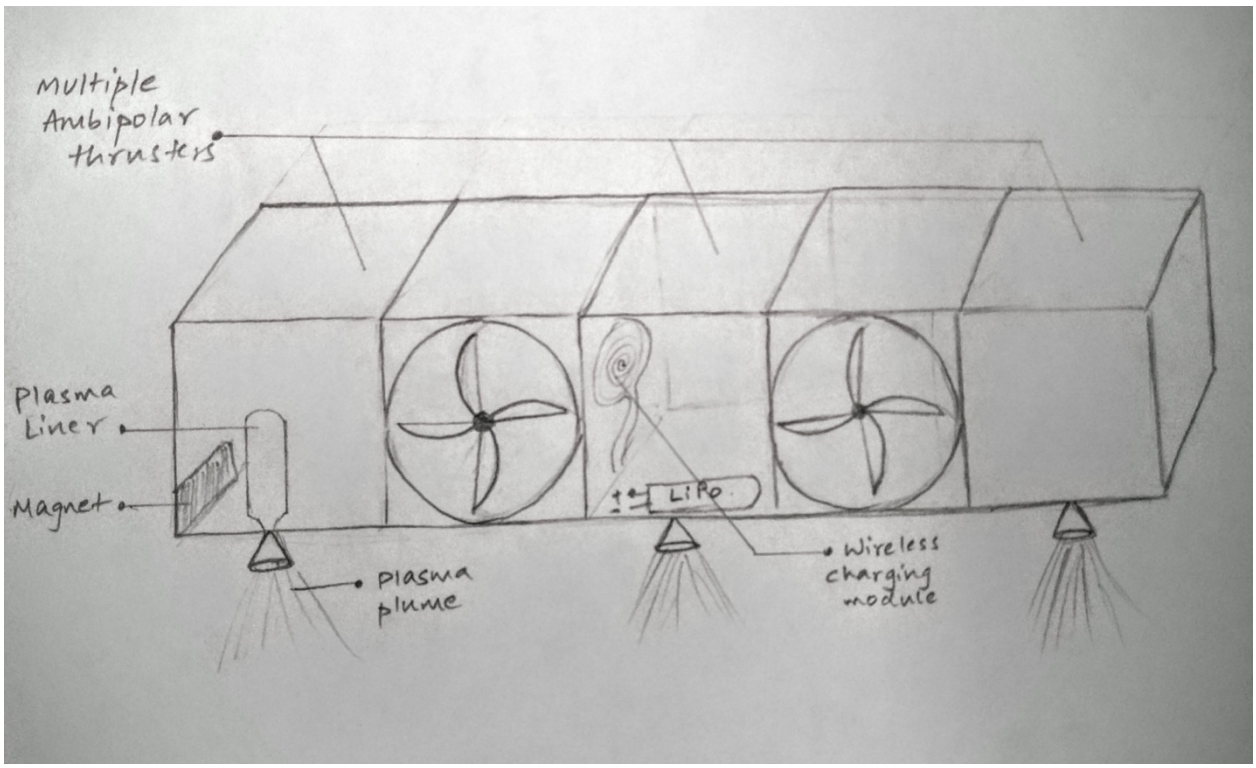

Figure 3, Stacked Upagrahas, interleaved with Ambipolar Thrusters

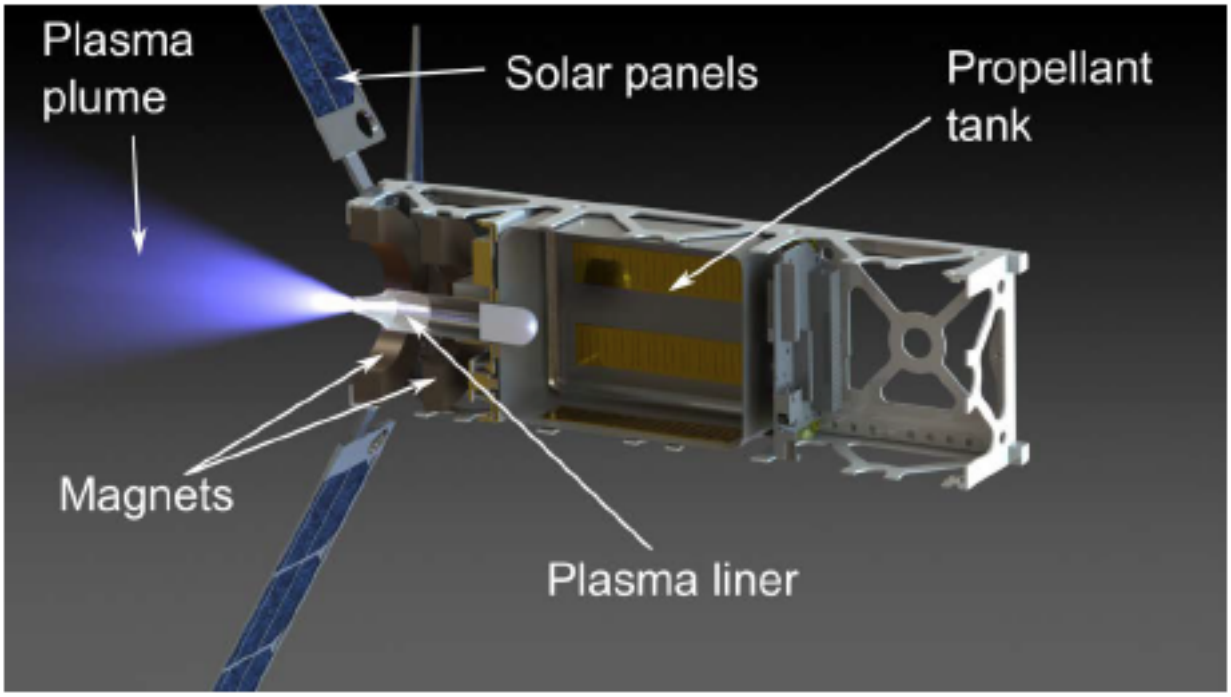

Figure 4, Ambipolar thrusters

U: Imaging

This Upagraha uses the NanoCam C1U by GOMspace. The NanoCam is a flexible system to rapidly implement tailored imaging systems based on the computer requirements. the camera has a 3MP color sensor which is capable of data processing and storage on-board. With a 4:3 aspect ration and a color CMOS sensor, the NanoCam 10-bit RGGB images of 2048 x 1536 P resolution. The imaging ultraviolet spectrograph (IUVS) has already proved to be successful in imaging mars from a distance of 23,000 miles. The IUVS provides global scale measurements of major molecules, atoms, ions and isotopes on Europa.

Figure 5, NanoCam C1U

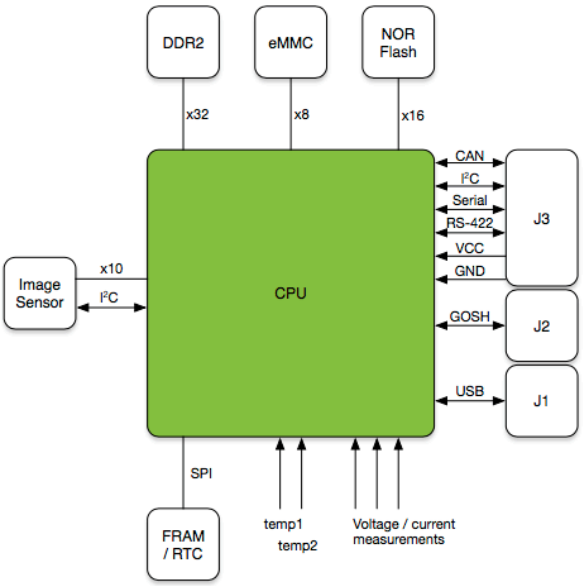

Figure 6, System Block Diagram(C1U)

U: Communication:

The Upagrahas come with a ISIS VHF downlink and UHF uplink full duplex transceiver. The ISIS TRXUV VHF/UHF Transceiver enables the CubeSat to have full duplex system with telemetry, telecommand & beacon capabilities on a single board. Its efficient BPSK downlink modulation scheme and flexible UHF receiver make it easy to communicate with the Upagraha.

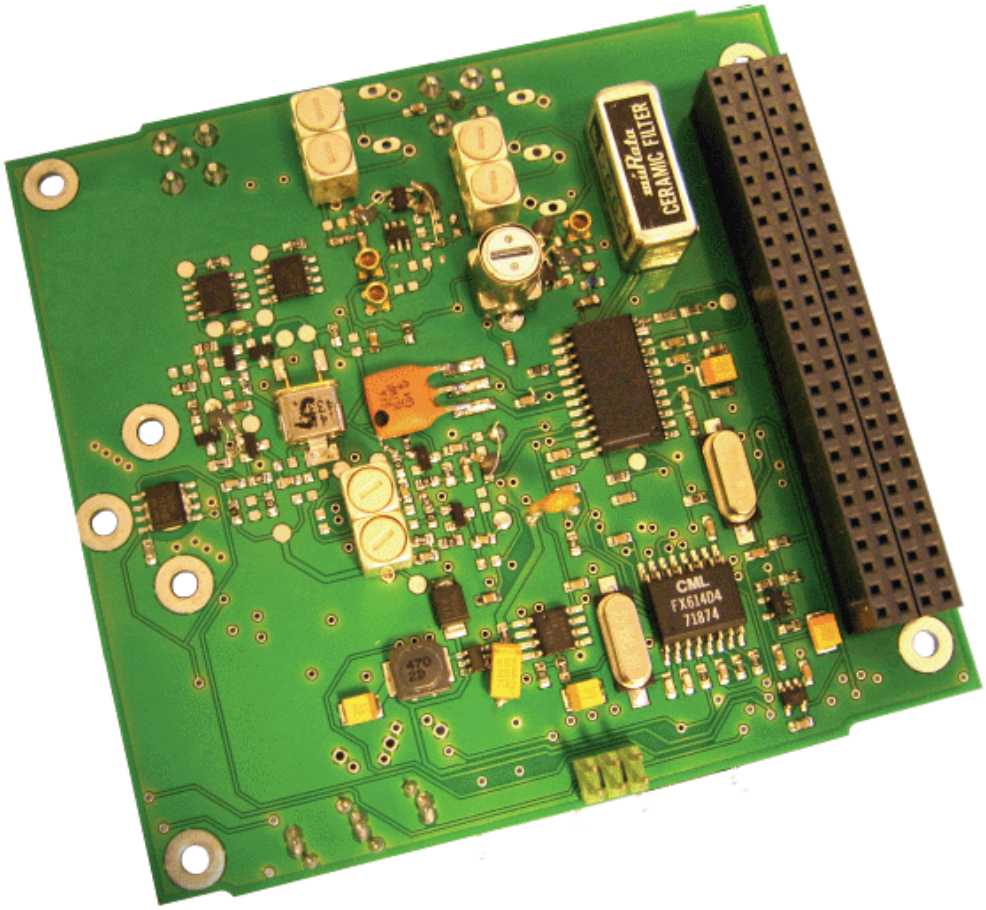

Figure 7, ISIS TRXUV VHF/UHF Transceiver

U: Locomotion

Every Upagraha has an independent Multiwii that is used to control the locomotion. The four sides of the Cube open out to form the four rotors of the quad-rotor. The control of the individual quad-rotors is achieved by altering the rotation rate of one or more of the rotor discs hence changing the torque load and thrust/lift characteristics. Each quad-rotor comes with four

brushless motors and Electronic Speed Controller (ESC). The rotation of motors changes as per the transmitted signal from the 6-channel transmitter. The signal from the microcontroller goes to the ESC's which control the speed of the motor.

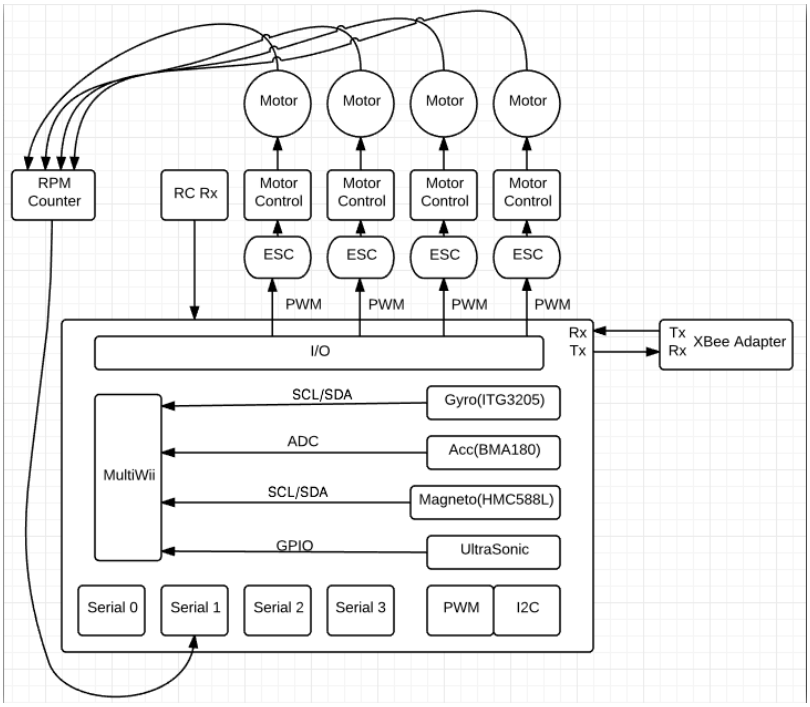

Figure 8, System Description - Quadcopter

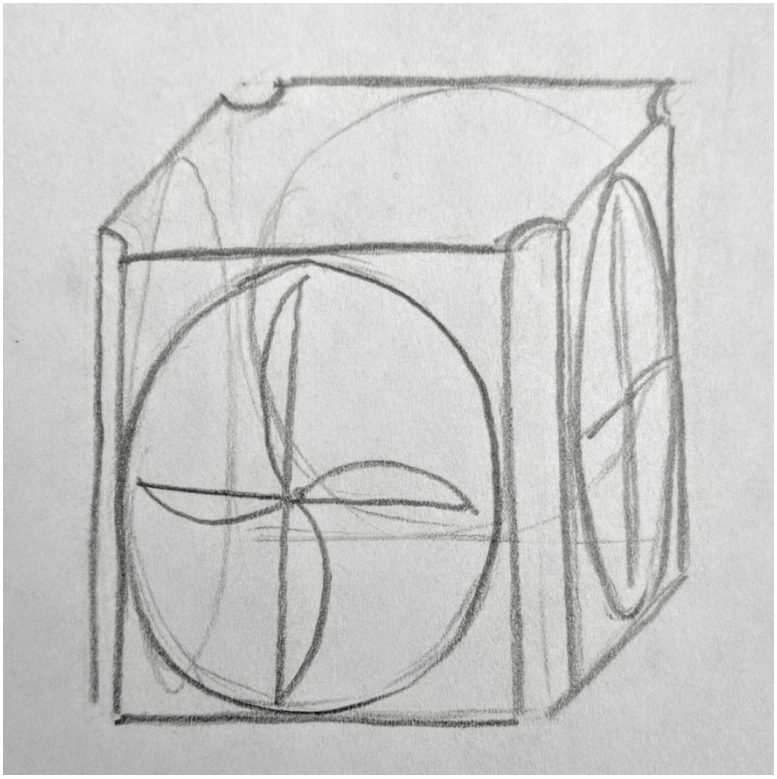

Figure 9, Any Nanosatellite after un-stacking. (Artist's interpretation)

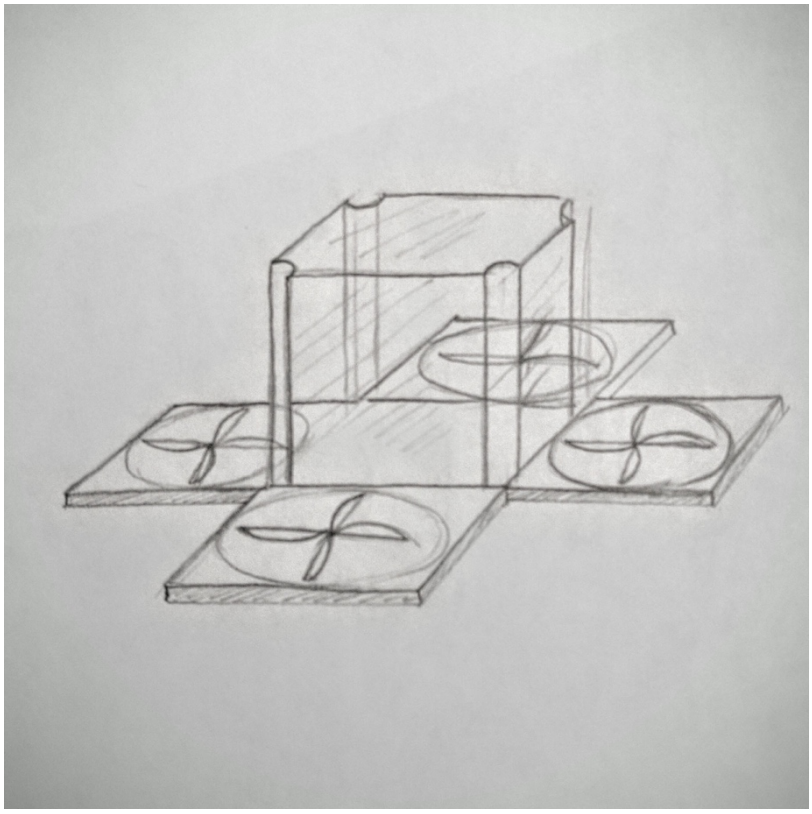

Figure 10, Transformation to Quadcopters, with enclosure to ensure electronics are safe.

TECHNICAL SPECIFICATIONS

Microcontroller: Arduino Mega 2560:
Input Voltage(recommended): 7-12V
Input Voltage(limit): 6-20V
Digital IO pins: 54 (15 with PWM output)
Analog Input Pins: 16
DC Current per I/O pin: 20mA
DC Current for 3.3V pin: 50mA
Flash Memory: 256KB
SRAM: 8KB
EEPROM: 4KB
Clock Speed: 16MHz

Weather Shield:
Humidity/Temperature Sensor: HTU21D
Barometric Pressure: MPL3115A2
Light Sensor: ALS-PT19

Microcontroller: MultiWii
SMD component design with Atmega2560
ITG3205 Triple Axis Gyro
BMA180 Accelerometer
BMP085 Barometer
HMC5883L Magnetometer
Servo output for camera pitch and roll control
Supports direct connection of GPS module (MTK 3329 GPS module included)
On-board USB connection for programming (MTK 3329 GPS Module)
Based on MediaTek Single Chip Architecture.
L1 Frequency, C/A code, 66 channels
High Sensitivity, Up to -165dBm tracking, providing superior urban performance
DGPS(WAAS, EGNOS, MSAS) support (optional by firmware)
USB/UART Interface.
Supports AGPS function.

GPS Shield
EM-406 connector populated
EM-408 and EB-85A connector footprints provided and connected for optional use
UP501 connector and footprint
Coin cell battery socket footprint provided and connected for optional battery backup of EB-85A GPS module
Standard Arduino sized shield

Prototyping area
GPS serial and PPS signals broken out to a 0.1" header for additional device connections
Arduino reset button
DLINE/UART switch controls serial communications
ON/OFF switch controls power to GPS module

Ambipolar Thrusters:
Up to 2 mN thrust for 10W (20mN for 100W pulsed)
Up to 20,000 m/s plasma exhaust velocity
Up to 10 Watts continuous (or higher power when pulsed)
>90% efficient solid-state DC to RF converter
Expected engine lifetime, >20,000 hrs of operation
Expected propellant: Iodine or Water
Expected propellant mass: <2.5kg (for a 3U CubeSat)
Permanent magnet converging-diverging nozzle

Inductive Charger:
Coil thickness: 1.75mm / 0.07"
PCB thickness (at tallest point): 3mm / 0.12"
Receiver weight: 5.5g
Transmitter weight 5.7g

NanoCam C1U:
Integrated System:
Industrial Lens
3-megapixel color sensor
Capable data processing and storage on-board
Image Acquisition:
1/2" (4:3) format color CMOS sensor
2048 x 1536 pixels
10-bit RGGB Bayer pattern
Lens Performance:
High-end industrial lens
35 mm f/1.9 or 70 mm f/2.2 standard lenses
35 mm lens: <60 m/pixel from 650 km
70 mm lens: <30 m/pixel from 650 km
400-1000 nm spectral transmission
Data Processing:
High performance ARM processor
512 MB on-board DDR2 RAM
2 GB solid state image storage
RAW, BMP and JPEG output format
Interface:

CSP-enable CAN, I^2C and TTL level serial interfaces
Serial port with text-based console

IUVS:
Imaging spectroscopy from 110–340 nm, with resolution of 0.5–1.0 nm.
Vertical resolution of 6 km on limb, horizontal resolution of 200km.
Detectors: Image-intensified 2-D active pixel sensors.

ESC:
Constant Current: 30A Burst Current: 40A Battery: 2-4S Lipoly / 5-12s NiXX BEC: 5v / 3A Motor Type: Sensorless Brushless
Battery Type: Lipo /NiXX Brake: On / Off Voltage Protection: Low / Mid / High Protection mode: Reduce power / Cut off power Timing: Auto / High / Low Startup: Fast / Normal / Soft PWM Frequency: 8k / 16k

BLDC:
Weight: 28g (kv1300) (not including connectors)
Diameter of shaft: 3.1mm Length of front shaft: 9.6mm
Lamination thickness: .2mm
Magnet type: 45SH
Voltage: 2~3S
Max current: 3.5~7.5A/20S
Propeller: 7x3.5~9x4.7
Pull: 250~470g

Motor Driver:
Power supply voltage: VM=15V max, VCC=2.7-5.5V
Output current: Iout=1.2A(average) / 3.2A (peak)
Standby control to save power
CW/CCW/short brake/stop motor control modes
Built-in thermal shutdown circuit and low voltage detecting circuit
All pins of the TB6612FNG broken out to 0.1" spaced pins
Filtering capacitors on both supply lines

SYSTEM DESCRIPTION:

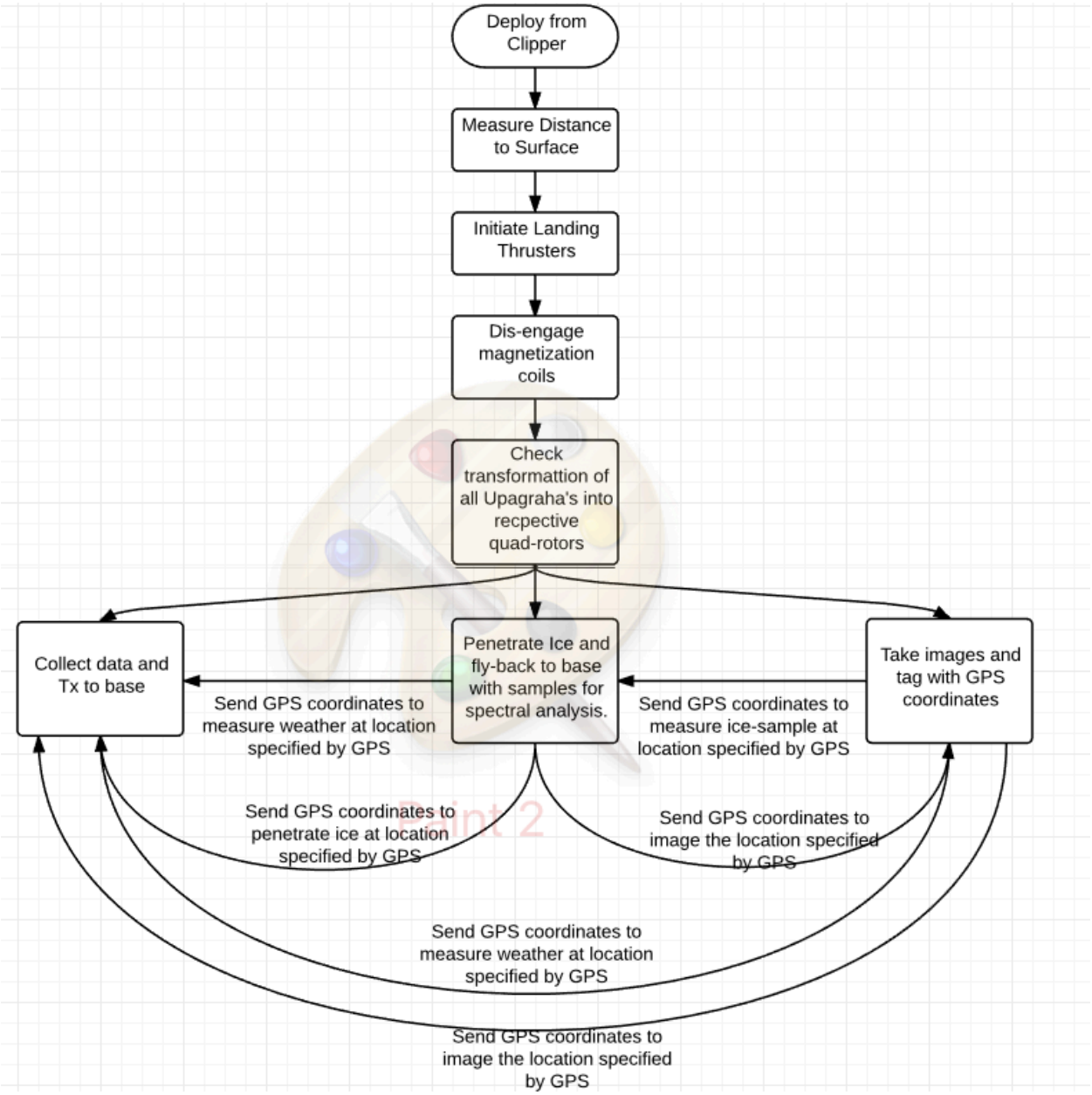

Figure 11, System behavior

LIST OF COMPONENTS:

Component	Model	Vendor	Details	Price($)
Weather Shield	12081	SparkFun	HTU21D MPL3115A2 ALS-PT19	39.95
GPS Shield	13750	SparkFun		14.95
AmbiPolar Thrusters		PEPL	Permanent magnet helicon generated plasma thruster	
Inductive charging setx4		Adafruit	5V @ 500mA	9.95
Nanocam	C1U	GOMspace	CMOS color sensor, 2048x536 res	
Transceiver		Cubesat shop	VHF/UHF transceiver	
IUVS			spectroscopy from 110–340 nm, 0.5–1.0 nm res.	
MWC Multiwiix4	SE V6.6	Ebay		56.99
Arduino MEGAx4		Ebay		13.16
Batteries	Turnigy	Hobbyking	22mAh, 3S 20C LiPo	9.99
ESC	Hobbyking	Hobyking	30A 3A	9.99
BLDC	Tunigy 2730	Hobbyking	2S, 3.5~7.5A20S	12.90
MotorDriver	TB6612FNG	Sparkfun	H-bridge dual motor driver	

Power Consumption:

With a 1Kg quad, a 1kg thrust is needed to defeat gravity; which is 250g thrust per motor. Each BLDC needs an ESC. The ESC regulates power to the motor according to the input throttle level. It also provides +5V power for the flight electronics. The the ESC is built on a 32 bit microcontroller (ARM) and an array of MOSFETs to drive the BLDC motor.

Operating System:

Arduino is an open-source prototyping platform based on easy-to-use hardware and software. Arduino boards are able to read inputs and turn it into an output - activating a motor, turning on an LED. One can tell the board what to do by sending a set of instructions to the microcontroller on the board. To do so, the Arduino programming language (based on Wiring) is used, and the Arduino Software (IDE), based on Processing. The Arduino Software (IDE) runs on Windows, Macintosh OSX, and Linux operating systems. Most microcontroller systems are limited to Windows. The Arduino software is published as open source tools, available for extension by experienced programmers. The language can be expanded through C++ libraries, and people wanting to understand the technical details can make the leap from Arduino to the AVR C programming language on which it's based. Similarly, AVR-C code can be added directly into Arduino programs if desired.

The functioning is divided into five tasks.

Task I: Using the thruster to land the magnetically stacked nanosatellites safely on the surface of Europa.

Task II: All the Upagrahas unfold to form the structure of the quad-rotor and send the ready signal to initiate the desired functionality. The imaging bundle uses the NanoCam C1U and takes hi-res images of the icy surfaces of Europa. On the other hand, the IUVS provides equally clear images of different light frequencies.

Task III: The Weather Station Upagraha monitors the air pressure, temperature, humidity at different locations. And all these are sent over the ISIS VHF/UHF transceiver to the Base Station.

Task IV: The ice probes are designed to penetrate the ice by generating heat from nuclear fission that is activated only when the position of the plunge site is confirmed via the inbuilt GPS module in every Multiwii.

Task V: There is a battery monitoring unit present in every Upagraha that checks the power requirement to navigate to the charging station and successfully dock and recharge the batteries. The displacement between the position of the Upagraha to the nearest charging station is calculated and the Upagraha is sent for charging.

COST ESTIMATE:

	Prototype Cost($)	Production Cost($)
Main Sysmtem Components	35,418	30,000
Frame	50	20
Discrete Components	100	50
PCBs	25	10
TOTAL	35,593	30,080

TIME ESTIMATE:

	Prototype	First Batch of Production
Physical Assembly	6 weeks	12 weeks
Testing and Bug Fixing	5 weeks	12 weeks
TOTAL	11 weeks	24 weeks

FUTURE IMPROVEMENTS:

Its inevitable that we think that autonomous cars have now reached the streets, why not nanosatellites. The next generation of nanosatellites will come with a highly developed AI network that will aid performance and quality of space exploration. Till now nanosatellites have not been used for battlefield communications. Future nanosatellites can provide, voice, data and

even visual aid to our war heroes which can eventually prevent thousands of deaths. Integrating the existing satellites, provide information to every other satellite and hence learn our solar system better would be where the next five to ten years of satellite research could be seen going.

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