# ARIC-2: Lightest Atmospheric Sounding Cansat

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***Abstract*–ARIC-2 is the fifth experience of ARI team with CanSats. The team goal in this project was to reduce the size of the main payload to the minimum possible to provide more available space for secondary payload. Secondary mission chosen for this CanSat is the line with forthcoming team activities, which may need bigger antenna sizes. The main and secondary missions have put the team members into high challenging situation which needed many recycles and tests.**

## I. Introduction

ARIC-2, CanSat designed and manufactured under ARI's team, is one of the steps to the team vision, low cost educational space system. ARIC-2 is an upgrade to its pioneer, ARIC-1, the CanSat with the main mission of telemetry and Comeback as side mission. ARIC-2 includes 2 payloads for its missions, Atmospheric Sounding and Antenna Deployment. The main objective of ARI projects on CanSat is to introduce the subject to all engineering students and show the ways to get a cheap and working space system like CanSat.

## II. Context of Development

### *A. Association*

Aerospace Research Institute CanSat Association (ARICA) is the first (and the only up to now) association in Iran concerning CanSat and amateur space systems. The main core of this association has been found about January 2010 by some aerospace engineering students, eager to work on low cost space systems and continue the research to form a large team from all over the country.

ARIC-2 is the fifth CanSat project done under this association with a team of five members (See Fig. 1) from different engineering majors, including aerospace engineers in system engineering part and electrical and mechanical engineers in technical part. System design was done based on previous experience on CanSats and lessons learned out of tests.

ARICA projects are not limited to CanSat and goes further to Balloon and Rocket Launchers, Sounding Rockets and BalloonSats. Currently, ARICA is organizing Iranian CanSat Competitions (ICC), started by first days of May 2011 and the event is planned for November 2011. This is the first of its kind and has faced an outstanding feedback from Iranian Universities. ICC website includes an English webpage integrating statistics for International viewers (http://www.ari.ac.ir/icc), as the goal of ARICA is to hold the second round with competitors from whole the world.

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ICC, concerned with all international and standard regulations and missions for CanSat, uses a balloon launcher to release the CanSats at an altitude of 500 meters. It is the highest altitude achieved in the whole balloon competitions (See Fig. 2).

Fig. 1. Picture of the ARIC-2 project team.


Fig. 2. Balloon Launcher and CanSat Tests

ARICA is in its first steps to desired, so any help and suggestions of friends and researchers from all around the world would be appreciated, as ARICA thinks global!

## B. *Work plan*

The Objective of ARICA in CanSat projects is to sustain low cost and optimum time-quality ratio for educational space systems. Normally, ARICA CanSat projects are done in a 6 month period and with a cost less than 500$. However the CanSat performance is dependent on the members' effort. ARIC-2 benefits an experienced team of a system engineer, 2 aerospace engineers, a Mechatronic engineer and an electrical engineer. The first three cover system design and mechanical subsystems, the last member is concerned with electrical design and manufacturing and the forth member control the interfaces and system specification to meet defined requirements.

ARIC-2 project was managed under the same team with the same ARICA policy, so it is planned to be done in a 6 month period, out of which 3 month is allocated to design process and the rest for fabrication and test. Design and manufacturing process was planned based on V-Diagram (See Fig. 3) in which each step can be validated by its parallel step in the same level. This makes the team to think and design based on what CanSat shall be.

The development process is scheduled on a time plan defined by a Gantt Chart presented in Fig. 4.

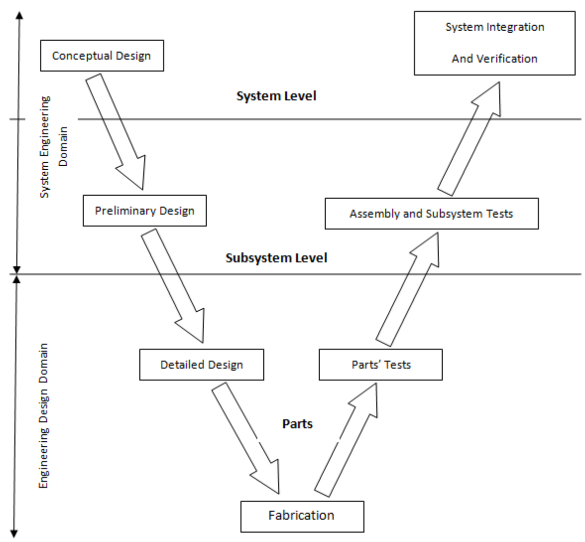


Fig. 3.V-Diagram [1]

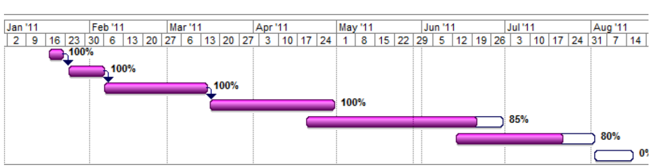


Fig. 4. ARIC-2 Project Gantt Chart [1]

The Gantt chart shown in Fig. 4 is the last update of the chart up to now, including project progress.

# III. DEFINITION OF THE MISSIONS

## A. *Scientific Mission – Atmospheric Sounding*

The main mission considered for ARIC-2 is Atmospheric Sounding, in which the outcome will be plots of atmosphere parameters versus altitude from the time of raising up to recovery and landing on earth [2]. ARIC-2 will measure parameters like Temperature, Pressure and Humidity and calculate the position to provide raw data for plots.

Beside the sensors and GPS module allocated to this mission, CanSat also includes an Accelerometer measuring acceleration in three axes. All data will be gathered with GPS location acquisition frequency (1Hz) in a package and will be sent to ground station in a real-time manner. Ground station has been designed especially for ARIC-2 and will be described fully in part V.

## B. *Free Mission – Deployment of Antenna*

ARIC-2 has chosen Deployment of Antenna as its secondary mission. This mission cannot be known as a free mission as its objectives and requirements are well known by the competition, but it is selected in the path of ARIC-2 team to future projects and ARICA vision. In this mission CanSat uses an antenna on which transmission of CanSat data is done during flight (stowed) and after deployment. The deployment of antenna will take place just after CanSat sensed landing impact based on change in accelerometer output [2]. Antenna is made up of a spring-like metal part, supported by a string strap

that will be cut by the time of deployment command. ARIC-2 team faced many new ideas and experiences during this mission since relatively low frequency chosen and dimension limits in standard class.

# IV. CANSAT ARCHITECTURE

ARIC-2 design and manufacturing was based on the objective to get the minimum volume occupied by CanSat. Modular system structure was then selected. CanSat is composed of 7 subsystems assembled into 2 modules, shaped circles in 60 mm dia. These circle shaped boards are connected to each other with connectors, supplying power and data lines. Two rods form the main frame of Structure subsystem, which will pass through the holes placed on the boards. Other subsystems including Payload-1, Payload-2, Onboard Computer (OBC), Communication Subsystem (COM) , and Electrical Power Subsystem (EPS) are introduced under Electrical architecture section. Recovery (RCV) subsystem is explained in Mechanical architecture part.

Structure subsystem function is to endure the loadings from preflight operation up to recovering CanSat on Earth. CanSat shape and dimension limits should be considered in design and manufacturing of CanSat structure, as the main outer body section of the CanSat .

Each of the following sections describe a numbers of subsystems which will be followed by some pictures.

## A. *Electrical architecture*

ARIC-2 electrical subsystems such as Payload-1, Payload-2, OBC and EPS are defined and designed in a modular way, as Payload-1 and COM are placed in Module-1 and Payload-2, OBC and EPS are placed in Module-2, the schematic board design of them are shown in Fig. 5.

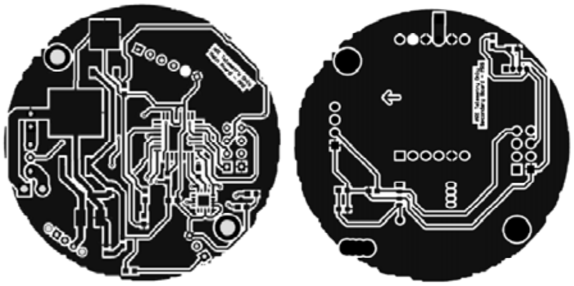

Fig. 4. ARIC-2 Electrical Boards Schematic (Module-1, Right; Module-2, Left) [3]

Payload-1 includes sensors MPXH6300A for Pressure measuring, SHT75 for Temperature and Humidity measurement, GT720F as GPS module and ADXL330 for accelerometer. Payload-2 is composed of an element cutting string by electrical burning. The idea of this element is used in small and nano satellites.

A processing chip, ATMega8, and the software on it, controlling whole CanSat functions, beside the data lines make the OBC subsystem. The software controls data gathering of the sensors and makes the required packet for transmitting and sends the deployment command. There is one kill switch in this CanSat, too, which will be Off when the CanSat releases from the Balloon, so it may show the release time.

COM subsystem uses a RXQ2 transmitter module and the antenna designed by the team, a small width spring metal with a stowed effective length of 11 cm (TBC) and deployed length of 26 cm (TBC). The CanSat cover a range of about 200 m with this transmitter and antenna, although it is highly dependent on Ground Station antenna, which more info will be given in the part V.

EPS supplies CanSat power by a 8.4 V Lithium-Polymer rechargeable battery with the capacity 550 mAh, supporting CanSat for more than 1.5 hours of function. Battery Connection has been designed in a place to replace the battery in a fast and easy way. The power to the whole system can be switched On/Off using the switch. There are also some regulators which deliver the required voltage and current to the parts. Power lines mainly are put under connectors to increase safety and simplicity in integration. Fig. 5 shows the first version of ARIC-2 which would not meet big changes to the final version.

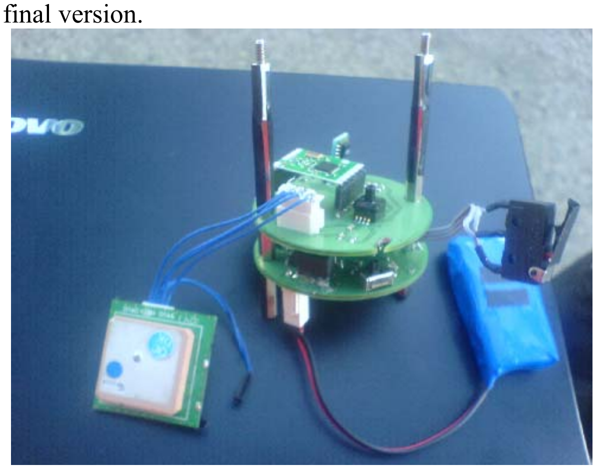

Fig. 5. ARIC-2 Version 1, so close to final version

## B. Mechanical parts

RCV is the main mechanical part of CanSat, composed of a parachute whose shape and size are totally defined based on experimental aerodynamics and the attachments to main structure. ARIC-2 uses semi-sphere shape with experimentally assessed Drag Coefficient ($C_D$) of 1.5 [3]. Considering a descent rate ($V_d$) of about 5m/s, the size of semi-sphere radius (r) will be found using (1):

$$r = \sqrt{\frac{2mg}{\pi \rho V_d^2 C_D}} \qquad (1)$$

in which m is the mass of CanSat, and ρ is the air density that is about 1.2 kg/m$^3$. With m about 300 gr, the radius of parachute would be 10 cm [3]. The connecting method of the parachute to the main structure is the next important subject in RCV design. This connection must be strong enough to face the parachute deployment and release loads, which has been measured about 3-5 gs. This connection uses a type of string which has shown a stiffness of enduring about 70 N loading (about 20g) and was tested many times in balloon releases for different CanSats. Parachute packing is the next critical point in RCV design, as it includes the main idea by which deployment of parachute may be assured. ARIC-2 uses a simple packing as the parachute is using a guaranteed fabric, many times tested for deployment and recovery (See Fig. 6).

Fig. 6. ARIC-2 Parachute Packing

The other mechanical part of CanSat can be found in the connection of antenna to the system. Antenna is connected to the system from its two ends. The former is attached to antenna port of transmitter via a non-transmitting cable from and the latter is supported by a fishing string to one of the structure rods, in way to let the Payload-2 mechanism burn the string for deployment at the right time.

Structure itself is selected based on previous experiences and a simple analysis on the loading in a balloon release and for the worst case in which the parachute fails. Rods and boards thickness has been selected for this loads with a safety factor of about 2.

## C. Ground Station

ARIC-2 sends all the data gotten from sensors in an string to the Ground Station (GS). This data include GPS location and altitude, sensors raw data, battery voltage and release and deployment status. The string starts and ends in a way to be only got by the ARIC-2 ground station. GS PC may show the raw data directly gotten from CanSat or process the data under GS software and show plots.

ARIC-2 GS has been designed and manufactured especially for this CanSat. As this CanSat is using a low frequency, low transmitting power transmitter module, it would be of great importance. Team has tested different antenna types in different shapes in order to cover an acceptable range more than what is needed in the competition (about 150 m). Fig. 7 shows a Fractal Antenna, one the antenna designed and tested under ARIC-2 team, with a nice result in receiving data in GS.

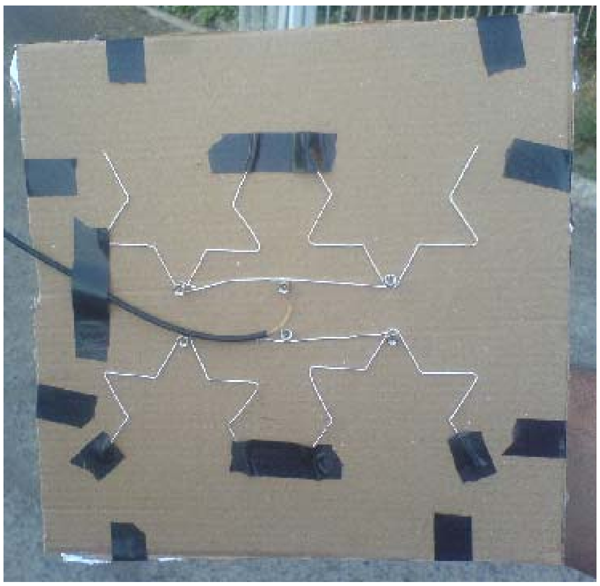

Fig. 7. ARIC-2 Ground Station Fractal Antenna (Early Version)

GS is designed very simple, taking the needed power to work from PC over USB port and also is simply attached and controlled on this port, too (See Fig. 8). GS may use different antennas, as this capability is enabled for it to change antenna in any time. There is a FT232 chip in GS hardware to make a virtual serial port, over which the data will be transferred to the computer screen. Data maybe delivered raw and real time on this port or processed and shown as plots in advance.

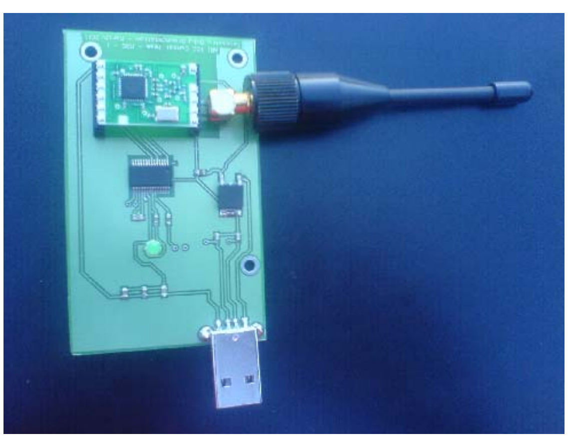

Fig. 7. ARIC-2 Ground Station

The LED used in the GS hardware indicates data transmission to PC over USB port. This LED is to assure data delivery in GS from CanSat. The antenna attached to GS, shown in Fig. 7 is a commercial helical antenna for 433MHz frequency with acceptable results in the tests.

## V. CanSat Budgets

In this part, the budgets allocated to each subsystem of CanSat in PDR will be compared to what is gotten during detailed design and manufacturing phase. Table 1 shows the budgets for Mass, Power and Cost for both Preliminary Design and Detailed Design phases in order to make a sense of design budget margins under development and manufacturing.

Table 1. CanSat Budgets [4,5]

| Subsystem | Element | Mass (gr) | | Power (mW) | | Cost (€) | |
|---|---|---|---|---|---|---|---|
| | | PDR | CDR | PDR | CDR | PDR | CDR |
| Payload-1 | Sensors | 60 | 11 | 150 | 130 | 100 | 50 |
| | GPS | | 8 | | 10 | | 40 |
| | Connections | | 22 | | 0 | | 5 |
| Payload-2 | Mechanism | 55 | 15 | 150 | 150 | 20 | 10 |
| | Connections | | 15 | | 0 | | 5 |
| OBC | Processor | 30 | 9 | 50 | 30 | 30 | 8 |
| | Kill Switch | | 13 | | 10 | | 2 |
| | Connections | | 23 | | 0 | | 10 |
| COM | Transmitter | 40 | 8 | 100 | 100 | 50 | 30 |
| | Antenna | | 26 | | 0 | | 15 |
| EPS | Battery | 50 | 35 | 50 | 0 | 70 | 40 |
| | Regulators | | 8 | | 30 | | 10 |
| | Switch | | 3 | | 5 | | 2 |
| | Connections | | 10 | | 10 | | 8 |
| RCV | Parachute | 55 | 27 | 0 | 0 | 40 | 20 |
| | Attachments | | 11 | | 0 | | 5 |
| STR | Rods | 60 | 58 | 0 | 0 | 90 | 15 |
| Total | | 350 | 302 | 500 | 475 | 400 | 275 |

The data in Table 1 shows approximately 15% margin in mass, 5% margin in power and 25% margin in cost for CanSat present state comparing to preliminary design budgets [3].

## VI. Test Plan

### A. Functional Tests

CanSat and its subsystems should pass different functional test to get ready for the operation day. Functional tests have been done on different subsystems individually and in accordance with each other.

Payload-1 tests include testing sensors' drivers, data collection and check on electrical connections. These tests are to prove functionality of electronic parts.

Payload-2 functional tests are done over deployment mechanism of antenna, to see if it is functional and it is working at the right time. These tests are done along with OBC tests which may include more tests like software checks and data packet collection.

COM tests include Signal Pattern tests and verification and coverage range tests. These tests may be done beside GS tests which are the same as COM functional tests.

EPS also undergoes tests like battery performance checks and regulation tests. Another test on EPS may be done to see operational performance of it under simulated conditions of mission.

RCV functional tests are of high importance. These tests are Drop Test, Strength Test, Operational Test, and Shock Test. Drop test is done with a dummy CanSat to check descent rate. Strength test is done on shroud lines and connections of parachute to main CanSat structure. Operational test checks the quality of descent to verify that CanSat drift is not more than a range defined (about half of release altitude). Shock test is a necessary one done on the parachute and connection material to see if they are strong enough to endure shock loading of release and deployment of parachute.

Structure must pass the tests like those on RCV, including Strength Test and Shock Test. The contents of these tests are the same as one in RCV.

Integrated CanSat must pass these functional tests:

- Data Delivery (Sending the telemetry packet from CanSat and receiving in GS)
- Transmission Range (Transmission of data over a defined distance with direct view)
- System Operational Time (Calculating the time that CanSat will remain operational with a fully charged battery)

Passing these tests, CanSat is ready for the flight [3].

### *B. Acceptance Tests*

After passing functional tests, CanSat should pass the integrated tests with the balloon launcher. The tests include dimension checks, data delivery during raise and recovery, release performance, parachute deployment after release, antenna deployment on ground impact and functionality after landing. These tests should be repeatable to show that CanSat has this ability to perform the operation for times.

## VII. Conclusion

By the time of writing this technical paper, ARIC-2 has passed all of its functional tests with success. All the requirements have been applied in the design by the ideas made in the team. CanSat has passed the first set of the tests with just Payload-1 operating and the second set of the tests will be done in near future for full functional and operational ARIC-2. Up to the time of second set of the tests, Electronic member is working on Calibration of the sensors to achieve the least possible error and Mechatronic member is going to make GS software compatible with the data received on virtual serial port. Based on this advancement, ARIC-2 project is lead to the time plan set for it.

## Acknowledgment

We thank DGA-EM to welcome us on their military base for the flights demonstration of CanSat in 2011. Also, ARICA's supports during design and development of this CanSat is highly appreciated.

## References

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