Microwave Remote Sensing Based On Small Satellite (MR3S)

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Introduction

Satellites employ rare and expensive radiant tolerant, radiation hardened or at least military qualified parts for computational and other subsystems to ensure reliability in the harsh environment of space.
Another distinguishing feature of the space architectures is the ad-hoc construction of electronic components, computers, controllers, power distribution unities, deployment systems, etc. Only few elements are inherited from previous missions.

Objective

A new paradigm is proposed based on commercial parts and components which are incorporated in an architecture to reach the expected identical reliability figures than a satellite using space qualified design. The small satellite market is offering a lot of space proven Commercial Off The Shelf (COTS) equipment and parts that are attractive (from the quality, cost and performance point of view) to be used on larger satellites, it is necessary to take note that the current expected lifetime for a CUBESAT is less than two years and the required lifetime for other satellites are around 60 months.

Reliability Principles

Reliability is the ability of a system to function under stated time and conditions. Assuming that the system is normally operative at t_0. The conditional probability that the system remains in the same state in the period $[t_0, t]$.
Because $R(t)$ is the probability of the system remains in continuous operation in the time range, $[t_0, t]$, the system's Mean Time To Failure (MTTF) and the Mean Time Between Failure (MTBF) are closely related by,

$$\text{MTTF} = -\int_0^\infty t\, dR(t) = \int_0^\infty R(t)\, dt\,.$$

If the system lifetime follows an exponential distribution, that is, $f(t)$ is a constant λ, i.e $R(t) = e^{-\lambda t}$. Then

$$\text{MTTF} = \int_0^\infty e^{-\lambda t}\, dt = \frac{1}{\lambda}$$

Availability $A(t)$ is the proportion of time during which the system is available within $[t_0, t]$. It can be calculated using, $A(t) = \text{MTTF}/\text{MTBF}$

Configurations

The three configurations are used to describe the reliability model.

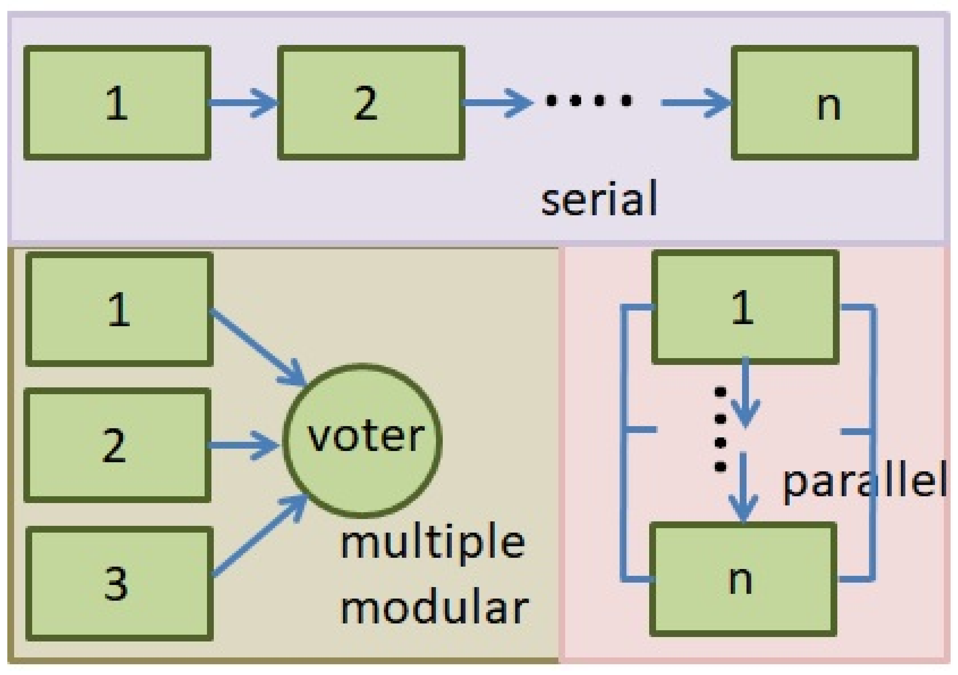

Fig. 1: Serial, Parallel and MMR configurations.

MR3S

The selected payload is a bi-static radar composed by two GPS receivers sharing the same time base.
The GPS signal reaches the GPS antenna on the satellite Zenith, and the scatter on the surface reaches the GPS antenna on the satellite Nadir.
The correlation between them allows to analyze data on the scattering area.

Reliability Model

Model	Reliability $R(t)$ =
Serial	$\prod_{i=1}^{n} e^{-\int_0^\infty \lambda_i\, dt}$
Parallel	$1 - \prod_{i=1}^{n} [1 - R_i(t)]$
MMR$^{(**)}$	$R_M(3\, e^{-2\lambda t} - 2\, e^{-3\lambda t})$

Model	Failure $\lambda(t)$ =
Serial	$\sum_{i=1}^{n} \lambda_i(t)$
Parallel	$\frac{\lambda(e^{-\lambda t}+e^{\lambda t})-2\lambda e^{-2\lambda t}}{2\, e^{-\lambda t}-e^{-2\lambda t}}^{(*)}$

Table 1: $^{(*)}$ for two identical units in parallel, $^{(**)}$ Multiple Modular Redundancy for three components which at least two should be operative.

Fault tolerance structure can be divided into cold-backup and hot-backup methods.

Configuration	Reliability $R(t)$ =
Cold Backup	$2\, e^{-\lambda t} - e^{-2\lambda t}$
Hot backup	$(2\, R_i(t) - R_i(t)^2)\; R_c(t)$

Table 2: Cold Backup: Only one equipment is powered on, Hot Backup: All units are power on.

GPS Reflectometry

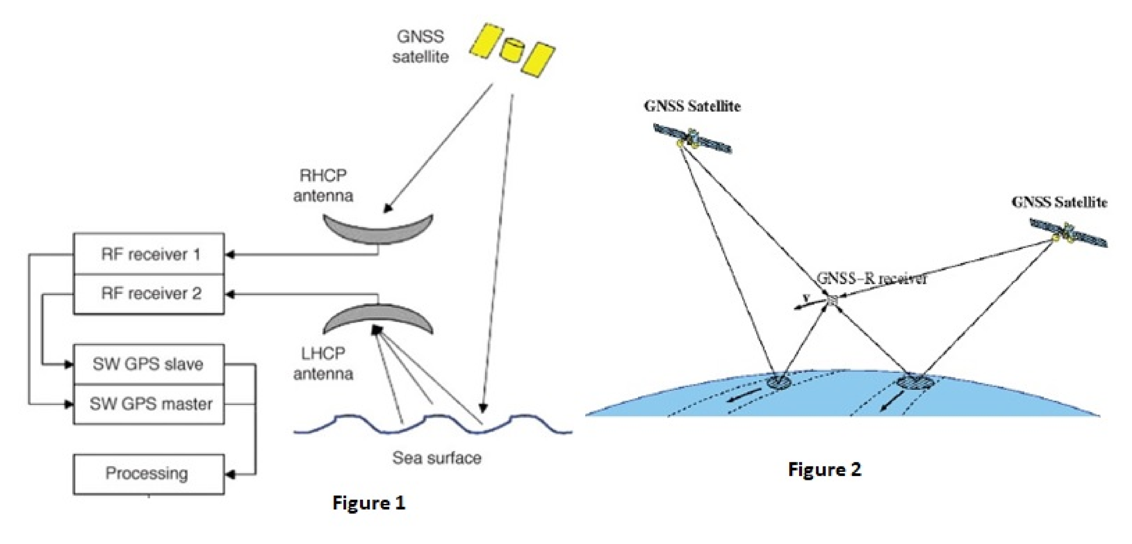

Fig. 2: General Concept for GPS reflectometry .

Characteristics

Based on the reliability analysis applied on the COTS products of the CUBESAT market, the design includes three components in most of the electronics parts to assure a lifetime of 5 years, which is a common requirement.
Only the voting electronics and the actuators need to be selected from COTS components out of the CUBESAT possibilities.
The GPS receivers are not included in the list, because the payload is based on that equipment.

Part	Quantity	Quality	Comments
PC/Plat.	3	CSAT	CC
PC/Payl.	3	CSAT	CC
Voting	3	Ad Hoc	2oo3
Tx	3	CSAT	CC
Rx	3	CSAT	HC
RW+TR	4+3	NoCSAT	HC.
TAM+ST	3+3	CSAT	HC.
X-band	3	CSAT	CC
Antennas	2+2	CSAT	HC.

Table 3: CSAT: Cubesat technology, NoCSAT: COTS but not Cubesat, CC: Cold Configuration, HC: Hot Configuration, 2oo3: Two out of three

Proposed Design

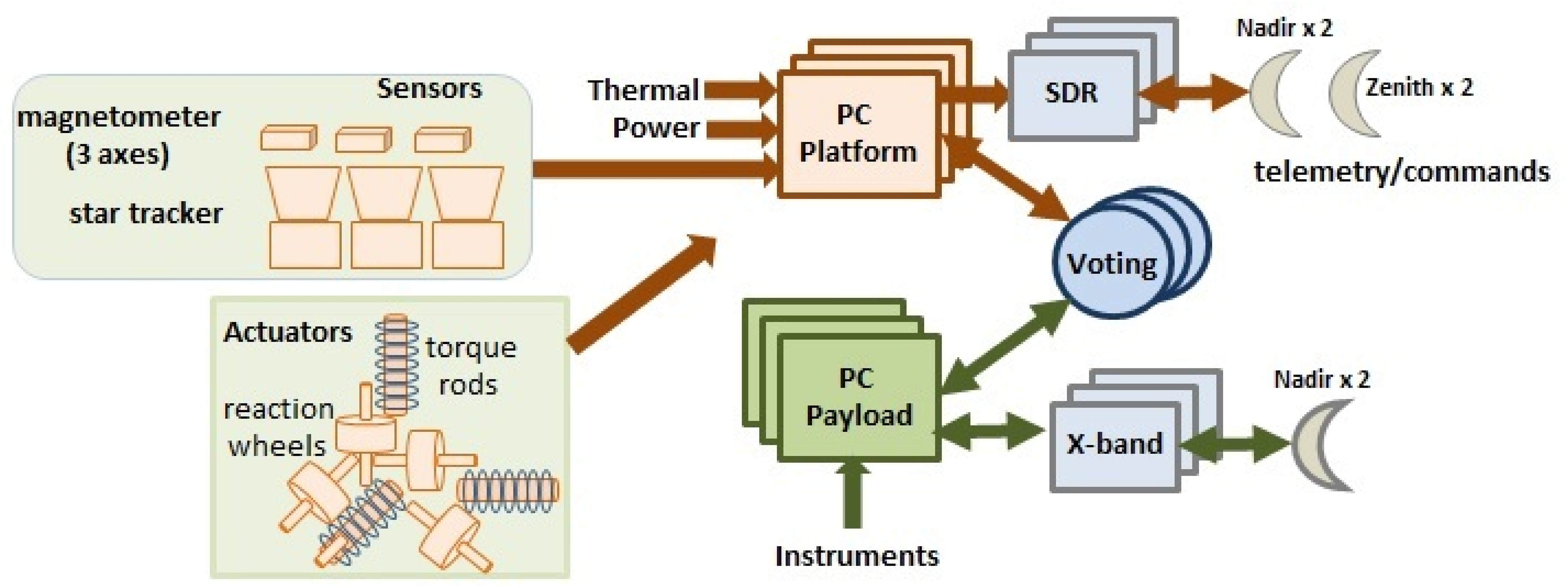

Fig. 3: Proposed general configuration, based on COTS components.

Conclusion

- Based on reliability analysis is possible to build a satellite based on COTS components, mainly coming from the CUBESAT market.
- The mass increase due to the addition of extra equipment is compensated with cost, time and simplicity reduction.
- From the point of view of the resources needed the SAR based GPS is utterly effective, specially power and mass.
- The use of smaller satellite increases the chance of having a continuous mission.