Mission analysis and design

Description: This document is made to ensure that all groups working with the CubeSat on AAU agree on the design. However, we (the two ACS-groups) suggest that it is up to each group, for themselves to decide, how much of this document they choose to use as documentation in their own internal report used for project examination.

Important! The contents of this document has not been accepted or commented by all groups and is not final. Comments can be send to newsgroup "auc.cubesat.discussion" or if important brought up at the next steering group meeting.

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Subsystem: System-engineering.
Date: 11.10.01
Rev.: 1.0
File name: missionanalysis-111001-rev1.0.pdf
Path: http://www.control.auc.dk/˜ 01gr930/

Literature:

[1] Space Mission analysis and design, Wiley J. Larson and James R. Wertz, 2nd edition.

chapter 1

Mission analysis

This document describes the mission analysis made by groups 930 and 931 (ACS-groups). In its current form it uses "*732's Suggestion to a definition of the AAU CUBESAT mission*" of 4th October from newsgroup *auc.cubesat.discussion*. Section 1.1 has been made according to the book "Space mission analysis and design". For section 1.3 methods of slides from mm3 "Spacecraft Engineering" by Ron Noteborn have been used.

1.1 Mission statement

We are going to take pictures of the earth from a low earth orbit (LEO) satellite at approximately 600 km height. The pictures will be in the visible light spectrum. The pictures will be transmitted to a ground station and made public via the internet. The photo coverage will most likely be restricted within the scope of Denmark.

The CubeSat concept, developed by Stanford University, provides a fast development phase (within one year) and inexpensive launch possibility, for a LEO satellite. This fits ideally to the project based education form used at Aalborg University.

Primary mission: The primary mission objective is to show that Aalborg University students are able to design and build a satellite.

Secondary mission :

- To communicate with the satellite while it is in orbit.
- To take a picture of the earth and transmit it to a ground station.
- To let people via the Internet choose a geographic site to be photographed and then later retrieve the photo.
- Hereby increasing public interest in space science, technology and natural science in general.

1.2 System requirements and constraints (p.15 used)

In this section requirements and constraints for the system are described. The system requirements must be defined to live up to mission objectives while the constraints limit the design. The functional requirements define how well the system must perform and the operational requirements determine how the system operates and how users interact with it. Using the CubeSat concept affects both the operational requirements and constraints.

Functional requirements

Performance: Take satellite photo of a location in Denmark. (performance: area, resolution and location accuracy)

Coverage: The number of times that the orbit of the satellite pass over Denmark, will set a limit to the number of photos to be taken per day. A realistic goal for daily coverage is one satellite photo of a location in Denmark per day.

Responsiveness: Communication between satellite and the ground station located in Denmark, is also limited by the amount of times the satellite passes close over Denmark. Requested photo is send back to ground station within a day. System status for the satellite can be send to ground approximately every ten hours.

Operational requirements

Duration The satellite will take pictures for as long as it is functional. The survivability of the satellite depends on the components used.

Availability Communication between ground station and satellite is only possible in the short time the satellite is above the horizon seen from the ground station. In LEO this will be a little less than approximately 15 minutes (best case). The satellite will pass close over Denmark 2 or 3 times every twelve hours (it is necessary to experiment a little more with Matlab simulations and provide documentation - documentation will follow soon).

Survivability In order for students and professors, working with the satellite at AAU, to have a reasonable amount of time to experiment with the satellite, the goal is to expand its lifetime in LEO environment to at least a year. This also means that it should be able to take and to send at least 365 satellite photos to the ground station in its lifetime.

Data distribution One ground station is used to communicate with the satellite. This is to be purchased and placed at the University of Aalborg.

Data content, form and format To make transfer time shorter, the photographic material should be compressed before it is send to the ground station. The coordinate for the geographic site is sent together with the compressed photo. A data log with runtime status for the system should always be made during runtime and send to ground station. From ground station it must be possible to send commands to the satellite. If errors have been detected in the software on the satellite, new software parts have to be transferred to the satellite.

Constraints

Cost: launch: 50000 US Dollars, satellite: ??.

Schedule P-POD design schedule for satellite and documentation. Internal design schedules for organizing work between project groups. Deadlines for deliveries of project reports.

Regulations ?

Political ?

Environment Launch vehicle places satellite into LEO

Interfaces Operator interface at ground station is to be determined. User interface is a web-site, where a request can be made for a satellite photo of a geographic site in Denmark.

Development constraints Design must meet the design requirements set forth in the P-POD Payload Planner's Guide.

1.3 Functional analysis

The functional analysis starts out with two main functions of the system. The two main functions are "Acquire photographic material" and "Communicate with ground". Secondly the main function is split into sub-functions which leads to requirements for the system performance.

Main functions

For the system to carry out its mission described in section 1.1, the satellite must be able to communicate with ground and create a photographic image of a requested geographic site.

Acquire photographic material: This function is started when a new request is made for photographic material. It must then be decided when the orbit for the satellite during daytime comes near the geographic site to be photographed in order to plan the next photo job. In advance of reaching the site to be photographed, the direction pointed to by the camera must be controlled, in order to photograph the correct location. At the point in the orbit where the satellite is closest to the target coordinate, the geographic site is photographed.

Communicate with ground station: Communication can begin when the satellite, seen from the ground station, comes above the horizon. This means that the communication will take place every time the orbit of the satellite comes near the ground station. During communication the antennas must be pointed towards the ground station. The communication from satellite to ground station must include acquired photographic material and runtime status for the satellite. Communication from the ground station includes new requests for photographic material and commands for maintenance of the satellite.

The main functions are illustrated in figure 1.1. In the figure the term boundary is used to describe the place on the orbit, where control is started in order to point either the camera or the antennas towards their target. The satellite is supposed to photograph geographic sites in Denmark. Since the ground station is also placed in Denmark the two main functions are likely to run simultaneously. If power is not sufficient for both main functions to be running at the same time, only the main function for acquiring photographic material is to be executed. Communication will then be postponed for another orbit. However, if faults have been detected in the system for the satellite since last communication, it is more important to establish communication with the ground station. For the two main functions to be run simultaneously the antennas and the camera must be mounted on the same side of the satellite.

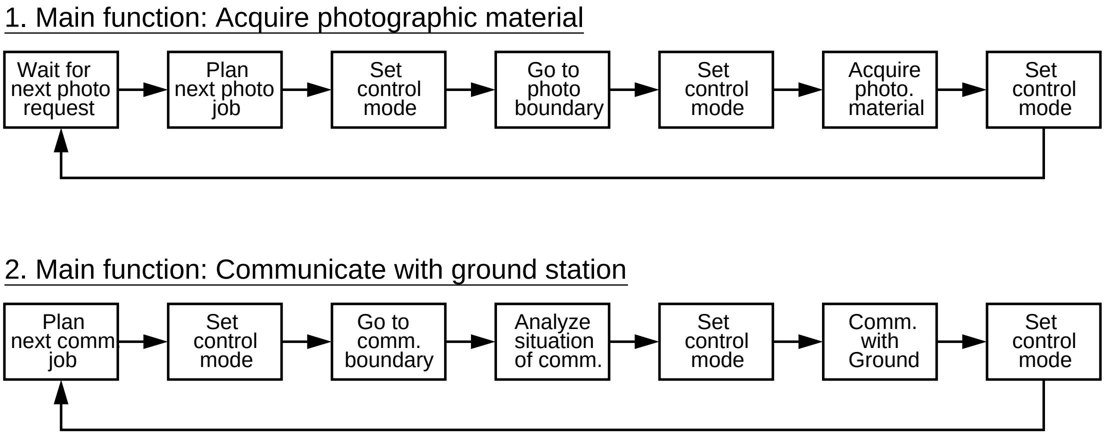

Figure 1.1: Both main functions first plans the upcoming job, then moves to the boundary with the control mode set to save as much power as possible. When reaching the boundary the control mode is set for either acquiring photographic material or communicating with ground.

In the previous description of main functions three types of control were considered.

- Control to point the camera towards the site to be photographed
- Control to point antennas towards ground station
- Control to save as much power as possible, perhaps by pointing solar panels towards the sun.

With a distance of approximately 600 km from the satellite to the earth, the control for pointing the camera towards a coordinate on the ground will require most precision. During communication the control is just to make sure that the body of the satellite does not block the signals. In the case where power is to be saved, the control to point the solar panels towards the sun in an optimal way, must not consume more power than gained. Furthermore the control of the satellite will be expanded to include fault tolerant control. This will introduce techniques to detect and accommodate faults in the control loops of the system. Furthermore control to detumble and stabilize the satellite after launch is necessary. In case of critical system failure in the attitude control system, it may be considered to implement a control to stabilize the satellite in order to enable communication to ground.

Functional breakdown

Here the sub-functions in each of the two main functions are divided into sub-functions. Some of the sub-functions will have requirements, that will be passed on to subsystems in the design. Sub-functions will not be made before main functions have been accepted.

1.4 System design

Important factors taken into consideration when developing the design for the satellite, are following in random order:

- Keep design simple, in order not to complicate and increase risk for errors in the system.
- Avoid unnecessary moving parts in design.
- The constraints described in section 1.1 must be taken into account.
- There is limited space and total weight must be kept under 1 kilogram, so this limits the amount of hardware.
- System must be divided into subsystems, with well defined interfaces, in order for work to be distributed between project groups.

To carry out the main functions described in section 1.3, the direction in which the camera, the antennas and the solar panels are pointed must be controllable. A few design options:

1. Use servo engines to make precise control of pointing direction for camera inside satellite. A simple attitude control is needed to stay in working area for servo engines. Direction of antennas and solar panels can be controlled with simple attitude control.
2. Antennas, solar panels and camera are fixed inside satellite, and pointed towards their target with precise attitude control.

Design option 2 is preferred over design option 1. In order to keep the design simple and avoid moving parts, the camera, antennas and solar panels will be fixed to the body of the satellite and pointed towards their target using attitude control for the satellite.

The hardware can be divided into subsystems as shown in figure 1.2.

More pages will follow to this document, when we have received comments on the first part.

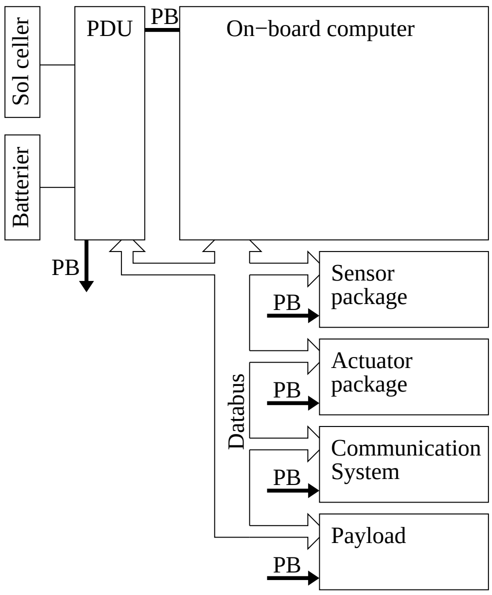

Figure 1.2: Blockdiagram describing hardware blocks of the system (PB = Power bus).