Technische Universität Berlin

Institut for Aeronautics and Astronautics (ILR)
Chair of Space Technology

TU Berlin - Fakultät V
Marchstraße 12-14
10587 Berlin
http://www.mse.tu-berlin.de

Master Thesis

Development of Electrical Power System Distribution Board for a 6 Unit satellite

Pavel Grigorev

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Supervised by
Prof. Dr. -Ing. Klaus Brieß

Assistant Supervisor
Dipl.-Ing. Daria Stepanova

Assistant Supervisor
Dipl.-Ing. Marc Lehmann

German Orbital Systems GmbH
Reuchlinstraße 10-11
10553 Berlin

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Last but not least, I would like to thank my family, specially my grandfather Vladimir, father Alexander and mother Elena for all the support on every decision that I have taken, for always being there. I dedicate this thesis to them.

Declaration of Authorship

I, Pavel Grigorev, hereby certify that this thesis has been composed by me and is based on my own work, unless stated otherwise. No other person's work has been used without due acknowledgement in this thesis. All references and verbatim extracts have been quoted, and all sources of information, including graphs and data sets, have been specifically acknowledged.

Berlin, 01.01.2050

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Pavel Grigorev

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Professor Dr.-Ing. Klaus Brieß
Head of the Chair of Space Technology

Abstract

Electrical Power System is a critical element in the success of a space mission. The main responsibility of Electrical Power System (EPS) is the energy generation, control and distribution for a satellite during the mission. Depending on a mission specifics, EPS is responsible for handling different power busses and loads and shall provide robust power channels to all spacecraft subsystems and payload. The Electrical Power System is also responsible for healthcare information collection and analysis.

Current work is dedicated to the development of a new EPS for 6 Unit CubeSat. Preliminary idea is to divide the EPS into two modules: Power Distribution (PDU) and Power Processing Unit (PPU). While PPU will be responsible for battery charging, energy conversion from the solar cells, power processing, PDU will be in charge of control and power monitoring. The present work will cover an architectural design of a whole system, while will be focusing on the design of a power distribution unit, which will be adjustable for different missions and responsible for a power handling.

This thesis aims to provide a full design iteration of a PDU of the 6 Unit CubeSat EPS. It will start with power budget analysis of 6U satellite. After that, the architecture of EPS distribution board will be reviewed. From the design side, electrical circuit and PCB of power distribution unit will be developed, manufactured and tested.

Keywords: Electrical Power System, 6 Unit CubeSat, Power Distribution, PCB design.

Zusammenfassung

Das Stromversorgungssystem ist ein entscheidendes Element für den Erfolg einer Weltraummission. Die Hauptverantwortung von Stromversorgungssystem (EPS) ist die Energieerzeugung, -steuerung und -verteilung für einen Satelliten während der Mission. In Abhängigkeit von den Missionsspezifikationen ist EPS für den Umgang mit verschiedenen Energiebussen und -lasten verantwortlich und muss allen Subsystemen und Nutzlasten des Raumfahrzeugs robuste Energiekanäle bereitstellen. Das Stromversorgungssystem ist auch für die Sammlung und Analyse von Gesundheitsinformationen verantwortlich.

Aktuelle Arbeiten widmen sich der Entwicklung eines neuen EPS für 6 Unit CubeSat. Die vorläufige Idee besteht darin, das EPS in zwei Module zu unterteilen: Power Distribution (PDU) und Power Processing Unit (PPU). Während die PPU für das Aufladen der Batterie, die Energieumwandlung aus den Solarzellen und die Stromverarbeitung verantwortlich ist, wird die PDU für die Steuerung und die Stromüberwachung zuständig sein. Die vorliegende Arbeit befasst sich mit dem architektonischen Entwurf eines gesamten Systems, wobei der Schwerpunkt auf dem Entwurf einer Energieverteilungseinheit liegt, die für verschiedene Missionen einstellbar ist und für ein Power-Handling verantwortlich ist.

Diese Arbeit zielt darauf ab, eine vollständige Design-Iteration einer PDU des 6-Einheiten-CubeSat-EPS bereitzustellen. Es beginnt mit der Analyse des Leistungsbudgets des 6U-Satelliten. Danach wird die Architektur des EPS-Verteilers überprüft. Auf der Entwurfsseite werden die elektrische Schaltung und die Leiterplatte der Stromverteilungseinheit entwickelt, hergestellt und getestet..

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1 Introduction

Due to significant amount of new Missions, German Orbital System took a step up to create a type of satellite bus for 6U satellite. As a result of updating the bus from 3U to 6U, satellite functions have improved, which opens up the possibility for more subsystems and components, as well as for payloads. The configuration of the separate power distribution unit made it possible to place more components on which the number of working subsystems and payloads increased. Development process of the satellite including EPS is taking a sizable amount of time, to use time more efficient was decided to divide the EPS in to two units and create an universal Power Distribution Unit which is admissible for 6 Unit as well as for a 3 Unit CubeSats.

1.1 Motivation

The motivation of this research is to find the optimal solution of the Power Distribution Unit architecture of Electrical Power System for the 6U CubeSat. Development of Power Distribution Unit will make a responsible use of time for a next missions, by development only a Power Processing Unit, which will be configured for each mission individually.

1.2 Objective

What kind of problem do you adress? Which issues do you try to solve? What solution do you propose? What is your goal? 'This thesis describes an approach to combining X and Y... The aim of this work is to...'

1.3 Scope

Here you should describe what you will do and also what you will not do. Explain a little more specific than in the objective section. 'I will implement X on the platforms Y and Z based on technology A and B.'

Conclude this subsection with an image describing 'the big picture'. How does your solution fit into a larger environment? You may also add another image with the overall structure of your component.

'Figure 1.1 shows Component X as part of ...'

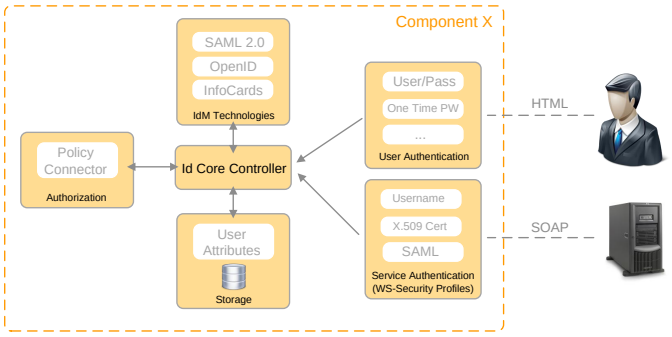

Figure 1.1: Component X

1.4 Outline

The 'structure' or 'outline' section gives a brief introduction into the main chapters of your work. Write 2-5 lines about each chapter. Usually diploma thesis are separated into 6-8 main chapters.

This example thesis is separated into 7 chapters.

Chapter 2 is usually termed 'Related Work', 'State of the Art' or 'Fundamentals'. Here you will describe relevant technologies and standards related to your topic. What did other scientists propose regarding your topic? This chapter makes about 20-30 percent of the complete thesis.

Chapter 3 analyzes the requirements for your component. This chapter will have 5-10 pages.

Chapter 4 is usually termed 'Concept', 'Design' or 'Model'. Here you describe your approach, give a high-level description to the architectural structure and to the single components that your solution consists of. Use structured images and UML diagrams for explanation. This chapter will have a volume of 20-30 percent of your thesis.

Chapter 5 describes the implementation part of your work. Don't explain every code detail but emphasize important aspects of your implementation. This chapter will have a volume of 15-20 percent of your thesis.

Chapter 6 is usually termed 'Evaluation' or 'Validation'. How did you test it? In which environment? How does it scale? Measurements, tests, screenshots. This chapter will have a volume of 10-15 percent of your thesis.

Chapter 7 summarizes the thesis, describes the problems that occurred and gives an outlook about future work. Should have about 4-6 pages.

2 Fundamentals and Related Work

Nowadays most of the companies designing their Electrical Power System boards for a nano cubesats as whole unit, consisted of all important devices for power management. This configuration is common and allowed to create space for a hardware in the tiny cubesat which is essential for a nano satellites due to its limited size and mass.

Despite the fact that mechanical space of the satellite is important, the space on the EPS board is also limited for a components which is limiting satellite possibilities with bigger missions and more developed bus.

2.1 Technologies

One unit configuration is a common type of an EPS design, which is mostly used by nano cubesat developers. This type of EPS design allowed to combine all components of the EPS in one unit to save mechanical space for the rest of the bus hardware and a payload of a nano cubesat. Second type of technology is a separated type of the EPS which is divided in to Power Processing Unit (PPU) which is responsible for a power generation from a solar panels, battery charging and balancing as well as power processing and power convertation and Power Distribution Unit (PDU) which has a function of the power distribution. PDU consist mostly of switchers and current sensors, this architecture allowed to place significant amount of switchers and connectors for a payloads, which is necessary for a missions requiring amount of payload connections which will not be enough for a standard one unit EPS board type.

2.1.1 Technology A

It's always a good idea to explain a technology or a system with a citation of a prominent source, such as a widely accepted technical book or a famous person or organization.

Exmple: Tim-Berners-Lee describes the "WorldWideWeb" as follows:
"The WorldWideWeb (W3) is a wide-area hypermedia information retrieval initiative aiming to give universal access to a large universe of documents." [BL]

You can also cite different claims about the same term.
According to Bill Gates *"Windows 7 is the best operating system that has ever been released"* [Gat] (no real quote) In opposite Steve Jobs claims Leopard to be *"the one and only operating system"* [Job]

If the topic you are talking about can be grouped into different categories you can start

with a classification. Example: According to Tim Berners-Lee XYZ can be classified into three different groups, depending on foobar [BL]:

- Mobile X
- Fixed X
- Combined X

2.1.2 Technology B

For internal references use the 'ref' tag of LaTeX. Technology B is similar to Technology A as described in section 2.1.1.

2.1.3 Comparison of Technologies

Name	Vendor	Release Year	Platform
A	Microsoft	2000	Windows
B	Yahoo!	2003	Windows, Mac OS
C	Apple	2005	Mac OS
D	Google	2005	Windows, Linux, Mac OS

Table 2.1: Comparison of technologies

2.2 Standardization

This sections outlines standardization approaches regarding X.

2.2.1 Internet Engineering Task Force

The IETF defines SIP as '...' [RSC+02]

2.2.2 International Telecommunication Union

Lorem Ipsum...

2.2.3 3GPP

Lorem Ipsum...

2.2.4 Open Mobile Alliance

Lorem Ipsum...

2.3 Concurrent Approaches

There are lots of people who tried to implement Component X. The most relevant are ...

3 Requirements

This section determines the requirements necessary for X. This includes the functional aspects, namely Y and Z, and the non functional aspects such as A and B.

3.1 Overview

In this chapter you will describe the requirements for your component. Try to group the requirements into subsections such as 'technical requirements', 'functional requirements', 'social requirements' or something like this. If your component consist of different partial components you can also group the requirements for the corresponding parts.

Explain the source of the requirements.

Example: The requirements for an X have been widely investigated by Organization Y.

In his paper about Z, Mister X outlines the following requirements for a Component X.

3.2 Technical Requirements

The following subsection outlines the technical requirements to Component X.

3.2.1 Sub-component A

Interoperability
Lorem Ipsum...

Scalability
Lorem Ipsum...

3.2.2 Sub-component B

Lorem Ipsum...

3.3 Social Requirements

Component X must compete with Y. Hence, it is required to provide an excellent usability. This includes ...

4 Concept

This chapter introduces the architectural design of Component X. The component consists of subcomponent A, B and C.

In the end of this chapter you should write a specification for your solution, including interfaces, protocols and parameters.

4.1 Sub-component A

The concept chapter provides a high-level explanation of your solution. Try to explain the overall structure with a picture. You can also use UML sequence diagrams for explanation.

Figure 4.1 illustrates the situation between Alice and Bob. (sequence diagram from www.websequencediagrams.com)

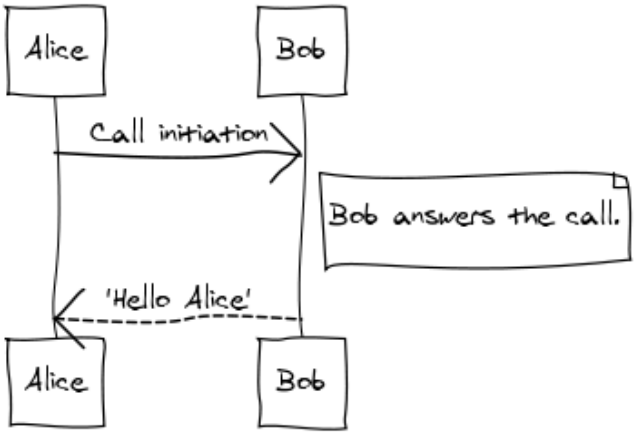

Figure 4.1: Alice and Bob

4.2 Sub-component B

Lorem Ipsum...

4.3 Proposed API

Lorem Ipsum...

4.4 Layer X

Lorem Ipsum...

4.5 Interworking of X and Y

Lorem Ipsum...

4.6 Interface Specification

Lorem Ipsum...

5 Implementation

This chapter describes the implementation of component X. Three systems were chosen as reference implementations: a desktop version for Windows and Linux PCs, a Windows Mobile version for Pocket PCs and a mobile version based on Android.

5.1 Environment

The following software, respectively operating systems, were used for the implementation:

- Windows XP and Ubuntu 6
- Java Development Kit (JDK) 6 Update 10
- Eclipse Ganymede 3.4
- Standard Widget Toolkit 3.4

5.2 Project Structure

The implementation is seperated into 2 distinguished eclipse projects as depicted in figure 5.1.

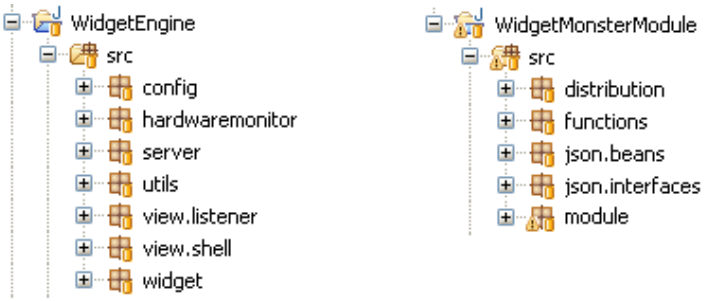

Figure 5.1: Project Structure

The following listing briefly describes the single packages of both projects in alphabetical order to give an overview of the implementation:

config
Lorem Ipsum...

server
Lorem Ipsum...

utils
Lorem Ipsum...

5.3 Important Implementation Aspects

Do not explain every class in detail. Give a short introduction about the modules or the eclipse projects. If you want to explain relevant code snippets use the 'lstlisting' tag of LaTeX. Put only short snippets into your thesis. Long listing should be part of the annex.

Listing 5.1: JSON String Code Snippet

```
{
        id: 1,
        method: "myInstance.getGroup",
        params: ["Teammates", 2, true]
}

{
        id: 2,
        result: [
                  "groupDesc":"These are my teammates",
                  {
                        "javaClass":"src.package.MemberClass",
                        "memberName": "Bob",
                  }
                ]
}
```

You can also compare different approaches. Example: Since the implementation based on X failed I choosed to implement the same aspect based on Y. The new approach resulted in a much faster ...

5.4 Graphical User Interface

Lorem Ipsum...

5.5 Documentation

Lorem Ipsum...

6 Evaluation

In this chapter the implementation of Component X is evaluated. An example instance was created for every service. The following chapter validates the component implemented in the previous chapter against the requirements.

Put some screenshots in this section! Map the requirements with your proposed solution. Compare it with related work. Why is your solution better than a concurrent approach from another organization?

6.1 Test Environment

Fraunhofer Institute FOKUS' Open IMS Playground was used as a test environment for the telecommunication services. The IMS Playground ...

6.2 Scalability

Lorem Ipsum

6.3 Usability

Lorem Ipsum

6.4 Performance Measurements

Lorem Ipsum

7 Conclusion

The final chapter summarizes the thesis. The first subsection outlines the main ideas behind Component X and recapitulates the work steps. Issues that remained unsolved are then described. Finally the potential of the proposed solution and future work is surveyed in an outlook.

7.1 Summary

Explain what you did during the last 6 month on 1 or 2 pages!

The work done can be summarized into the following work steps

- Analysis of available technologies
- Selection of 3 relevant services for implementation
- Design and implementation of X on Windows
- Design and implementation of X on mobile devices
- Documentation based on X
- Evaluation of the proposed solution

7.2 Dissemination

Who uses your component or who will use it? Industry projects, EU projects, open source...? Is it integrated into a larger environment? Did you publish any papers?

7.3 Problems Encountered

Summarize the main problems. How did you solve them? Why didn't you solve them?

7.4 Outlook

Future work will enhance Component X with new services and features that can be used ...

List of Acronyms

3GPP	3rd Generation Partnership Project
AJAX	Asynchronous JavaScript and XML
API	Application Programming Interface
AS	Application Server
CSCF	Call Session Control Function
CSS	Cascading Stylesheets
DHTML	Dynamic HTML
DOM	Document Object Model
FOKUS	Fraunhofer Institut fuer offene Kommunikationssysteme
GUI	Graphical User Interface
GPS	Global Positioning System
GSM	Global System for Mobile Communication
HTML	Hypertext Markup Language
HSS	Home Subscriber Server
HTTP	Hypertext Transfer Protocol
I-CSCF	Interrogating-Call Session Control Function
IETF	Internet Engineering Task Force
IM	Instant Messaging
IMS	IP Multimedia Subsystem
IP	Internet Protocol
J2ME	Java Micro Edition
JDK	Java Developer Kit
JRE	Java Runtime Environment
JSON	JavaScript Object Notation
JSR	Java Specification Request
JVM	Java Virtual Machine
NGN	Next Generation Network
OMA	Open Mobile Alliance
P-CSCF	Proxy-Call Session Control Function
PDA	Personal Digital Assistant
PEEM	Policy Evaluation, Enforcement and Management
QoS	Quality of Service
S-CSCF	Serving-Call Session Control Function
SDK	Software Developer Kit
SDP	Session Description Protocol
SIP	Session Initiation Protocol
SMS	Short Message Service

SMSC	Short Message Service Center
SOAP	Simple Object Access Protocol
SWF	Shockwave Flash
SWT	Standard Widget Toolkit
TCP	Transmission Control Protocol
Telco API	Telecommunication API
TLS	Transport Layer Security
UMTS	Universal Mobile Telecommunication System
URI	Uniform Resource Identifier
VoIP	Voice over Internet Protocol
W3C	World Wide Web Consortium
WSDL	Web Service Description Language
XCAP	XML Configuration Access Protocol
XDMS	XML Document Management Server
XML	Extensible Markup Language

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[BL] Berners-Lee, Tim: *WWW Book (no real book, just an example).*

[Gat] Gates, Bill: *no real citate.*

[Job] Jobs, Steve: *no real citate.*

[Joh03] Johnston, Alan B.: *SIP, understanding the Session Initiation Protocol, Second Edition.* Artech House Publishers, 2003. ISBN: 1580536557.

[RSC+02] Rosenberg, J., H. Schulzrinne, G. Camarillo, A. Johnston, J. Peterson, R. Sparks, M. Handley and E. Schooler: *SIP: Session Initiation Protocol.* RFC 3261 (Proposed Standard), June 2002. Updated by RFCs 3265, 3853, 4320, 4916, 5393.

Annex

```
<?xml version="1.0" encoding="UTF-8"?>
<widget>
         <debug>off</debug>
         <window name="myWindow" title="Hello Widget" visible="true">
                 <height>120</height>
                 <width>320</width>
                 <image src="Resources/orangebg.png">
                        <name>orangebg</name>
                        <hOffset>0</hOffset>
                        <vOffset>0</vOffset>
                </image>
                 <text>
                         <name>myText</name>
                         <data>Hello Widget</data>
                         <color>#000000</color>
                         <size>20</size>
                         <vOffset>50</vOffset>
                         <hOffset>120</hOffset>
                 </text>
        </window>
</widget>
```

Listing 1: Sourcecode Listing

```
INVITE sip:bob@network.org SIP/2.0
Via: SIP/2.0/UDP 100.101.102.103:5060;branch=z9hG4bKmp17a
Max-Forwards: 70
To: Bob <sip:bob@network.org>
From: Alice <sip:alice@ims-network.org>;tag=42
Call-ID: 10@100.101.102.103
CSeq: 1 INVITE
Subject: How are you?
Contact: <sip:xyz@network.org>
Content-Type: application/sdp
Content-Length: 159
v=0
o=alice 2890844526 2890844526 IN IP4 100.101.102.103
s=Phone Call
t=0 0
c=IN IP4 100.101.102.103
m=audio 49170 RTP/AVP 0
a=rtpmap:0 PCMU/8000

SIP/2.0 200 OK
Via: SIP/2.0/UDP proxy.network.org:5060;branch=z9hG4bK83842.1
;received=100.101.102.105
Via: SIP/2.0/UDP 100.101.102.103:5060;branch=z9hG4bKmp17a
To: Bob <sip:bob@network.org>;tag=314159
From: Alice <sip:alice@network.org>;tag=42
Call-ID: 10@100.101.102.103
CSeq: 1 INVITE
Contact: <sip:foo@network.org>
Content-Type: application/sdp
Content-Length: 159
v=0
o=bob 2890844526 2890844526 IN IP4 200.201.202.203
s=Phone Call
c=IN IP4 200.201.202.203
t=0 0
m=audio 49172 RTP/AVP 0
a=rtpmap:0 PCMU/8000
```

Listing 2: SIP request and response packet[Joh03]