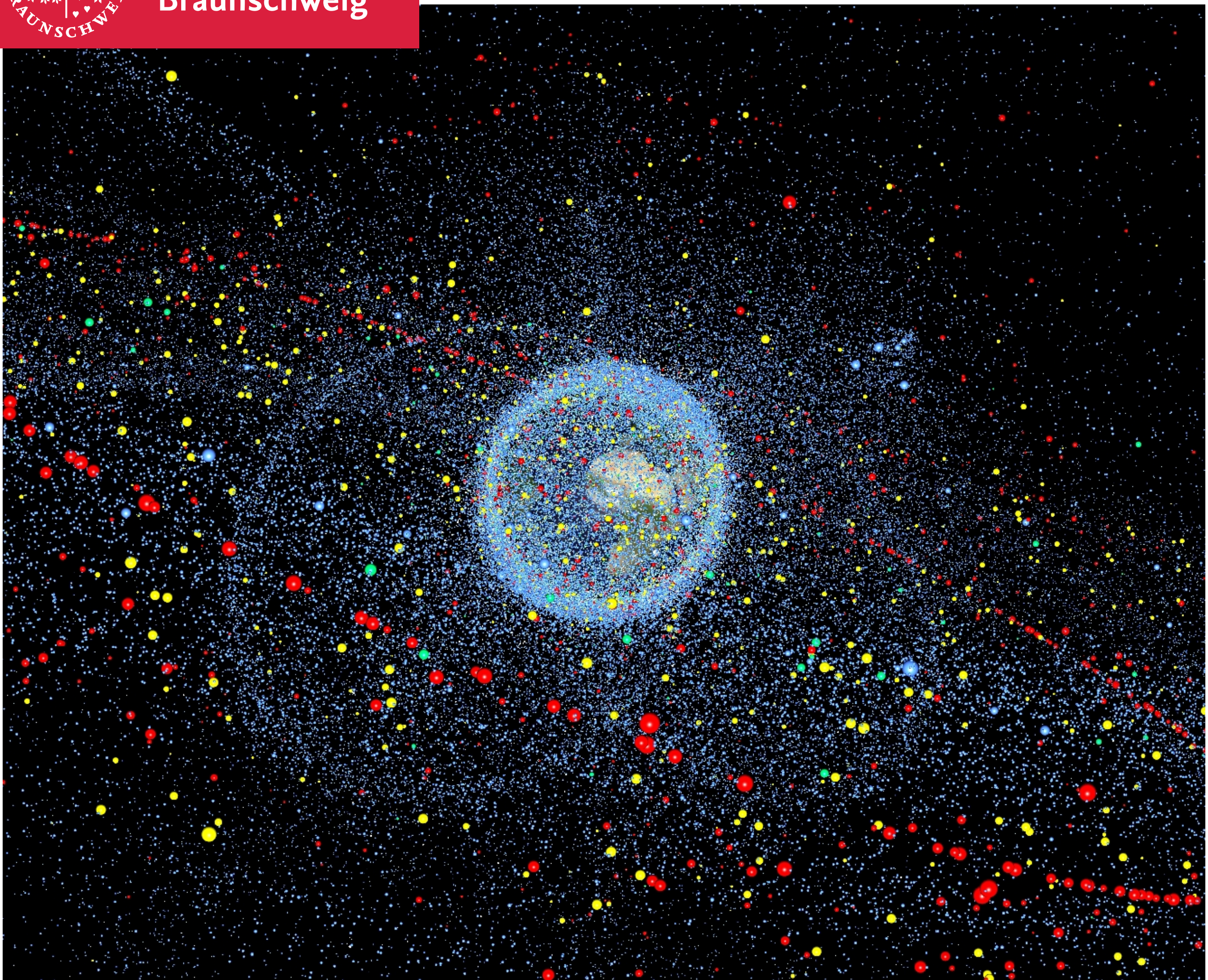
Technische Universität Braunschweig

Institut für Raumfahrtsysteme



R XXXX X
CubeSat-based active debris removal

Institut für Raumfahrtsysteme

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Datum: 01. Mai 2019

Ihr Zeichen:
Ihre Nachricht vom:
Unser Zeichen: EnS/KBL
Unsere Nachricht vom:

Aufgabenstellung für die Projektarbeit SS 2019

Title:
Analysis of a CubeSat-based ADR-Mission

Analyse einer ADR-basierten CubeSat-Mission

A safe and secure space environment is a requirement for all current and future space activities. Analyses performed by ESA and NASA indicate that the only means of sustaining the orbital environment at a safe level for space operations will be by carrying out active debris removal and end-of-life de-orbiting or re-orbiting of future space assets. While new mitigation standards need to be adopted and reliability to be improved, it is expected that even with strict compliance with mitigation guidelines and high adherence to reliability best practices, considering the number of satellites involved, ADR will remain a vital necessity to stabilize the space debris environment. The needed ADR solution must be affordable and achieve a high technology readiness level.

The key to success in achieving reliable and efficient removal of space debris is to focus on the recent evolution trends in space industry and take advantage from advances in space technology such as CubeSat COTS-parts to develop an adapted solution to the evolving space debris issue. The solution should be thoroughly tested and demonstrated in relevant environments.

To realize this, a series of technological challenges has to be addressed. The Goal of this work is to investigate **CubeSat-based ADR** mission. In particular the **mission design and the CubeSat system design** are to be analyzed. The following detailed tasks must be performed:

1. First of all, a literature research has to be performed based on the supervisor's previous works [1], including the following topics:
    a. Rendezvous mission and satellite design overview.
    b. Bio inspired Docking technology.
    c. CubeSat Hardware overview.

   d. Familiarizing with GMAT and QuSAD software.
2. Subsequently, the **mission and system design are to be defined** for a CubeSat based ADR mission. The work includes the following steps:
   a. Define relevant mission scenario for CubeSat based ADR using methodical approaches based on pervious works [1,2] and the results from task 1. This includes the specification of each mission phase in terms of number of: orbits (time), used sensors, used actuators, etc…
   b. Select a Bio-inspired docking concept based on the results of supervisor's on-going work and results from task 1.
   c. Define relevant CubeSat configurations based on basic budgets estimations and the results from [2].
3. Deliver a **proof of concept for mission and CubeSat design**. The Proof focuses on the feasibility of the de-orbit phase based on the selected CubeSat configurations and the constraints dictated by mission design and the CubeSat calculated budgets. The work includes the following steps:
   a. Update the database of the software tool QuSAD with all relevant subsystems.
   b. Perform detailed Budget evaluation of identified CubeSat configurations using methodical approaches based on the results from task 1, 2 and the report from [2].
   c. Perform detailed de-orbit sensitivity analysis of the selected CubeSat configurations using GMAT software.
   d. Define envelope of target parameters which can be removed using the selected concept
   e. Evaluate the feasibility of CubeSat-based ADR for prominent announced constellatiuons such as Starlink, OneWeb, etc…

4. The work described in points 1 to 4 shall be elaborated in writing and presented in a final presentation. The results, raw data as well as the created software tools are to be made available to at least one IRAS employee for archiving and further processing.

At the beginning of the work, a definition and description of individual work packages (Work Breakdown Structure, Work Package Description) are to be compiled to a project schedule. The work has to be done according to the guidelines of the Institute of Space Systems and has to be handed over in two copies (original and copy).

The Institute of Space Systems supports the scientific publication of the results of student work with prior approval. However, the results of the work may only be carried out after consultation with the supervising institutions. This work may be provided to third parties only after consultation with the supervising institutions. The work remains the property of the supervising institutions.

Literature:

[1] M.K. Ben Larbi et. al., *Active Debris Removal for Mega Constellations: CubeSat Possible?,* 9th International Workshop on Satellite Constellations and Formation Flying, 2017
[2] M. Lettau, *Rendezvous Architecture and Validation Process for CubeSat based Active Debris Removal,* Master thesis, TU Braunschweig, 2019

Dipl-Ing. Mohamed Khalil Ben Larbi

Eidesstattliche Erklärung

Wir erklären hiermit an Eides Statt, dass wie die nachfolgende Arbeit selbständig und nur unter Zuhilfenahme der angegebenen Literatur angefertigt haben.

Datum, Unterschrift Florian Czorny

Datum, Unterschrift Frederik Schäfer

Datum, Unterschrift Marc Strempel

Datum, Unterschrift Oussama Mouhaya

Datum, Unterschrift Valentina Dietrich

Übersicht

Inhaltsverzeichnis

1 Einleitung

1.1. Motivation

1.2. Problemstellung

1.3. State of the Art

Overview of cooperative RDVDO missions
Overview of uncooperative RDVDO mission

2 Theoretische Grundlagen

2.1. Das Cubesat Designstandard

2.1.1. Standard Definition

2.1.2. Historische Entwicklung

kurz **Anwendungsbereich Low-Budget LEO Experimente Interplanetar (InSight) Active Debris Removal Cubesat Misisonen** Übersicht über bisherige launches und deren payload (Daten und ein Bild zum anpassen existieren schon)

2.2. Cubesat Subsysteme

hier Hauptsächlich das Fazit von max kompakt darstellen und refernzieren

2.2.1. Antrieb - propulsion

2.2.2. Energie - EPS

2.2.3. Guidance, navigation and control -GNC ADCS

2.2.4. Command and data handling

2.2.5. Communications

2.2.6. Thermal

2.2.7. Structure

2.3. RDVDO Mechanismen

das kann ausführlich sein

2.3.1. Docking Strategien

Roboterarm Fangnetz Adhäsiv Docken Übersichtstabelle/Graphik: sihe die Quellen die ich am 15.05.2019 gezeigt habe

2.3.2. Bionische Materialien

Was sind Geckomaterialen Bisher getestete Gecko-Materialien Bisherige Erfolge State of the Art Problematik

3 Cubesat-und Missionsdesign

3.1. QuSAD

3.1.1. Was ist QuSAD

3.1.2. Anwendungsbereich

3.2. Cubesat- Designanalyse

3.2.1. Angenommenes Design

Hier die Varainte von Max nehmen und kurz beshcreiben

3.2.2. Triebwerkskonstelation

Hier alternative Triebwerkskonstellationen bzw. Anpassungen des Gesamtdesigns (wenn nötig) vorschlagen **Triebwerskonstellation 1**
Triebwerskonstellation 2
Triebwerskonstellation 3
etc.

3.2.3. Budgetplanung

Leistungsbudget
Massenbudget
Volumenbudget
Preisbudget

3.2.4. Konfigurationsvergleich

Budgets nur Vergleichen (kein GMAT)
Datenbank soll möglichst nicht nur um die einzelnen Kompenenten erweitert werden (ruhig auch andere Komponenete aus der Excel Tabelle ind die Datenbank aufnehemn)

3.3. Ausgewähltes Missionsdesign

Kurze Beschreibung uas Max's Arbeit

4 Auswertung des CubeSat-based ADR Konzepts

4.1. Bewertungsstrategie

Die Strategie besteht draus mehrere Simulationen per GMAT für untershciedliche Koonfigs durchzuführen. Die Bewertung fokusiertsich auf die Machbarkeit des De-orbiting (seihe TODOS.txt)

4.1.1. Kriterien der Bewertung

4.1.2. GMAT

4.2. Ergebnisse

4.2.1. Generated Data

For every considered satellite design (=mainly thruster configuration, 3-4 different designs), generate following data:

Deorbit time and spent fuel mass for all:

- Masses from 50-500 kg
- Altitudes from 1400-400? km (ggf. semi-major axis)
- Eccentricities from 0 to highest recorded eccentricity of debris in <1400 km orbit

Note: Output EVERY relevant simulation parameter (initial orbit and S/C data, burn start/stop angles, start epoch etc.) at the beginning of every simulation run [discuss with Max]

4.2.2. Reachability Enveloppe

RESULTING DIAGRAMS:

1. Visualize the absolute performance of the main design (Max), e = 0
   - Axes: y = mass, x = SMA
   - Graph: Use color gradients to display deorbit times (same time = same color)

2. Visualize the influence of eccentricity on deorbit times using the main design
   - Axes: y = mass, x = SMA
   - Select a fixed deorbit time (e.g. 2 years)
   - Graph: Use color gradients to display eccentricities (same ecc = same color)
3. Visually compare the performances of the different designs (Max & 2-3 group designs), e = 0
   - Axes: y = mass, x = SMA
   - Select 1-2 fixed deorbit times (e.g. 2 years & 5 years)
   - Graph: Draw lines of same deorbit time (selected above) for each of the different designs

Optional for group after 3. (decide if worth it)
4. Repeat 1. with all other chosen designs

NOTES:

For 1. & 4.:
(Deorbit time limited to 10 years (15? 20?))
-> <2 years of deorbiting takes 3-4 mins to simulate, amount of data is immense => limit maximum deorbit time?
-> At which deorbiting time does a feasible solution become unattractive? If 200 kg in 1000 km orbit is
deorbitable in 20 years, is it worth it? Better use chemical deorbiting = different mission in this case?
—> Agree on a meaningful limit on deorbit time

For all graphs/simulations:
Fuel mass limited by design -> if 27U standard is to be kept no matter which thruster configuration is
chosen, then smaller/more lightweight thrusters would result in more available space for fuel
—> Agree on a set percentage of margin for all designs (e.g. 50%) and determine maximum fuel from there?

-> For Max's design, fuel mass limited to 10 kg (thinking about increasing to 15 kg)

5 Zusammenfassung und Ausblick

Fazit und Ausblick

Literaturverzeichnis

Abbildungsverzeichnis

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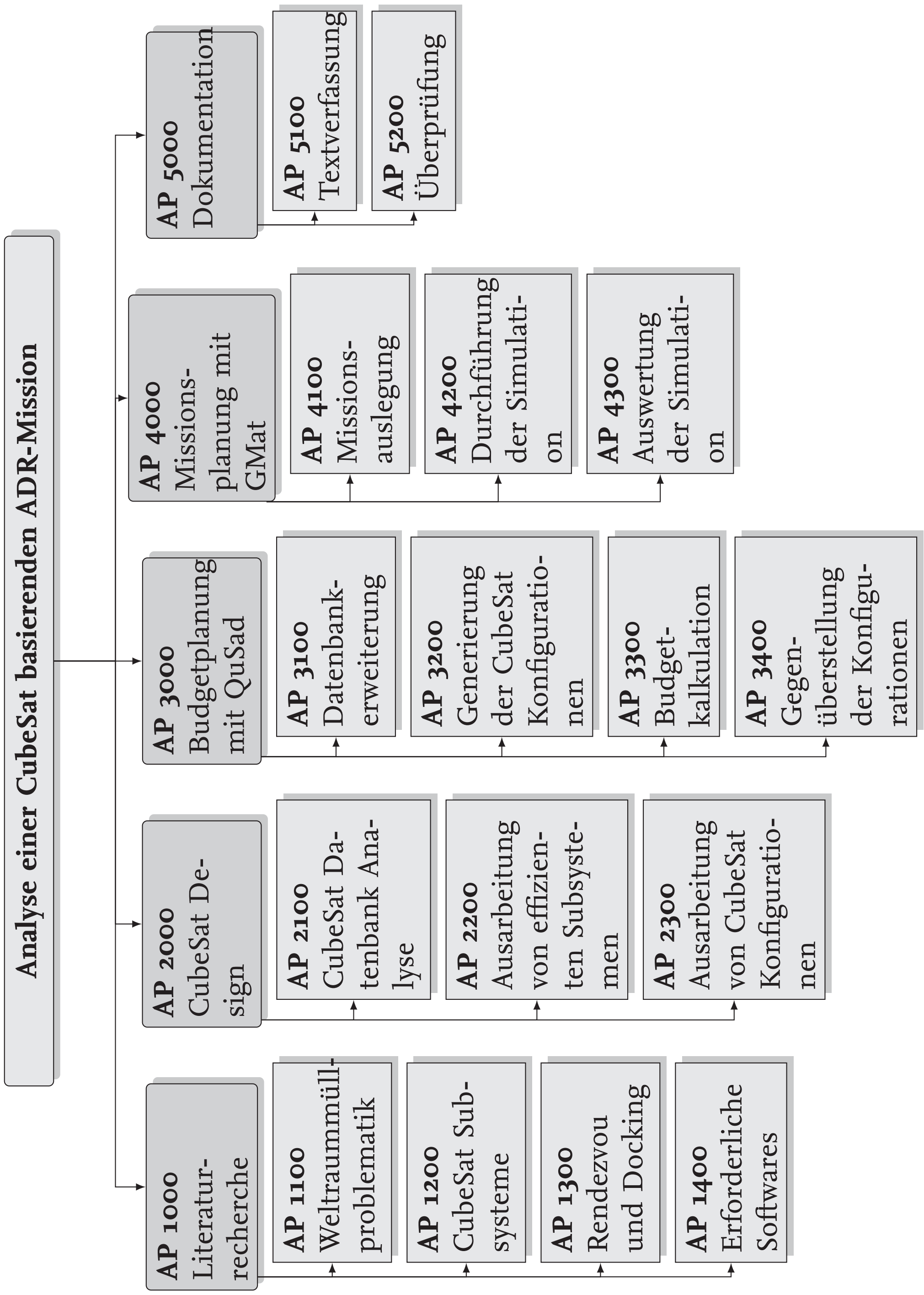
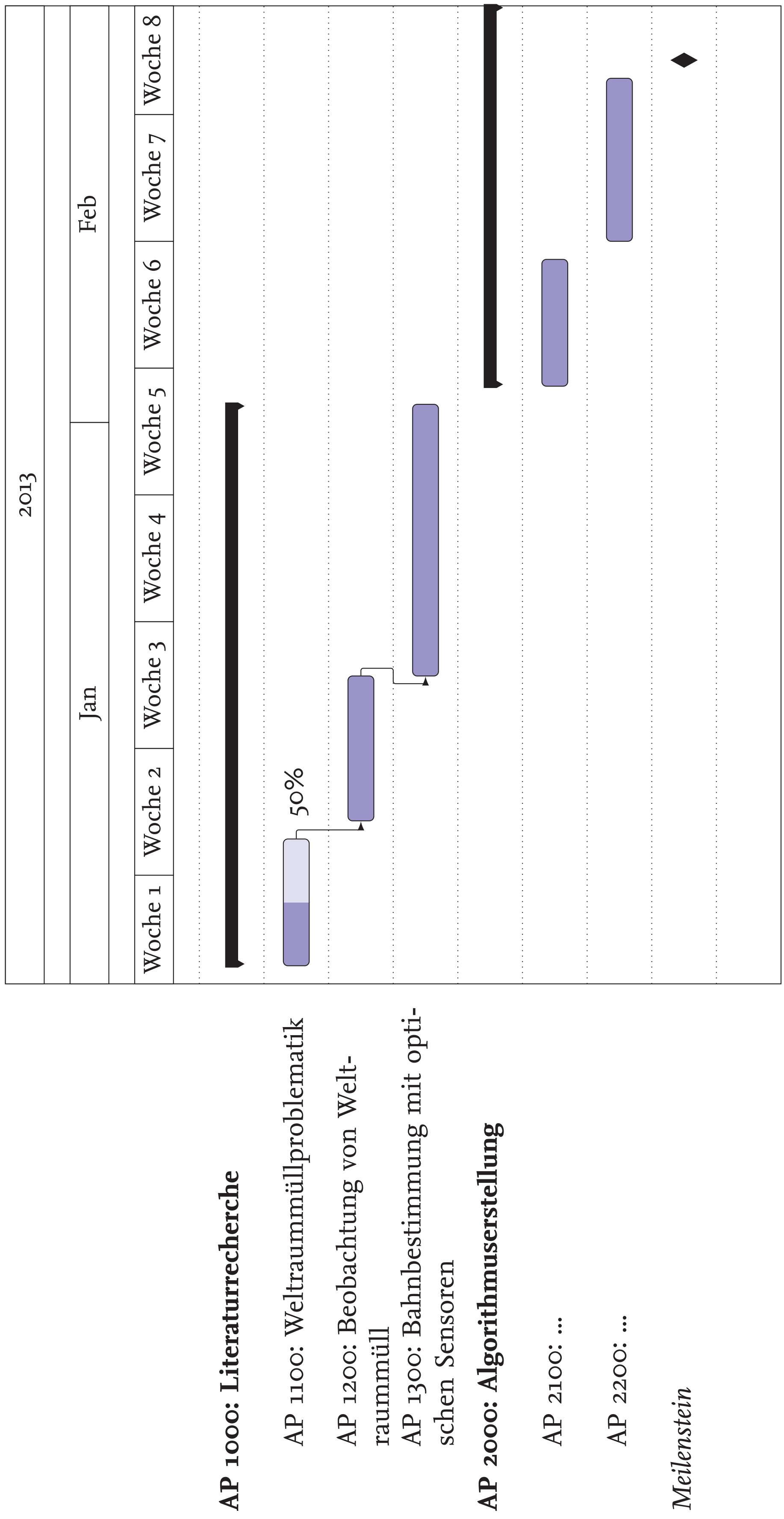
Symbolverzeichnis

A Projektmanagement

A.1. Work Breakdown Structure


Analyse einer CubeSat basierenden ADR-Mission
AP 1000 Literatur-recherche
AP 1100 Weltraummüll-problematik
AP 1200 CubeSat Sub-systeme
AP 1300 Rendezvou und Docking
AP 1400 Erforderliche Softwares
AP 2000 CubeSat De-sign
AP 2100 CubeSat Da-tenbank Ana-lyse
AP 2200 Ausarbeitung von effizien-ten Subsyste-men
AP 2300 Ausarbeitung von CubeSat Konfiguratio-nen
AP 3000 Budgetplanung mit QuSad
AP 3100 Datenbank-erweiterung
AP 3200 Generierung der CubeSat Konfiguratio-nen
AP 3300 Budget-kalkulation
AP 3400 Gegen-überstellung der Konfigu-rationen
AP 4000 Missions-planung mit GMat
AP 4100 Missions-auslegung
AP 4200 Durchführung der Simulati-on
AP 4300 Auswertung der Simulati-on
AP 5000 Dokumentation
AP 5100 Textverfassung
AP 5200 Überprüfung

A.2. Zeitplan


2013
Jan
Feb
Woche 1
Woche 2
Woche 3
Woche 4
Woche 5
Woche 6
Woche 7
Woche 8
AP 1000: Literaturrecherche
AP 1100: Weltraummüllproblematik
50%
AP 1200: Beobachtung von Welt-raummüll
AP 1300: Bahnbestimmung mit opti-schen Sensoren
AP 2000: Algorithmuserstellung
AP 2100: ...
AP 2200: ...
Meilenstein

A.3. Work Package Description

		AP 1100
Titel	**Genauigkeit der Bahnbestimmung von Space Debris-Objekten mittels weltraumgestützter optischer Sensoren**	**Seite:** 1 von 1
Verantwortlicher	Sebastian Stabroth	**Version:** 1.0
		Datum: 25.06.2003
Beginn	T_0	
Ende	T_0+1 Woche	**Dauer**: 1 Woche
Bearbeiter	Sebastian Stabroth	

Ziele:
• Kenntnis über die Weltraummüllumgebung, Bahnbereiche von Space Debris-Populationen, Objektanzahlen und -größen

Input:
• Literatur zum Thema Weltraummüll

Schnittstellen zu anderen APs:
• **AP 5100** zur Simulation der Bahnbestimmung von Weltraummüll

Aufgaben:
• Einlesen in die Thematik Weltraummüll

Ergebnisse:
• Verständnis der Weltraummüllproblematik

		AP 1200
Titel	**Titel des Arbeitspakets**	**Seite:** X von Y
Verantwortlicher	Dein Name	**Version:** 1.1
		Datum: DD.MM.YYYY
Beginn	T_0	
Ende	T_0+X Wochen	**Dauer:** X Wochen
Bearbeiter	Dein Name	

Ziele:
- Ziel 1
- Ziel 2
- ...

Input:
- Input 1
- ...

Schnittstellen zu anderen APs:
- **AP XXXX** Beschreibung
- **AP ....** ...

Aufgaben:
- Aufgabe 1
- ...

Ergebnisse:
- Ergebnis 1
- ...