PROBA-V

SPACE DEBRIS MITIGATION DOCUMENT

EN-34-VES

EUROPEAN **S**PACE **A**GENCY CONTRACT REPORT

This document may only be copied, distributed and utilised or its contents communicated to others either with prior written permission of Verhaert Design & Development or in accordance with the terms of **ESA contract no.** 22218/09/NL/GLC.
Offenders will be held liable for payment of damages. All rights reserved, in particular the right to carry out patent, utility model or ornamental design registration.

The work described in this report was done under ESA contract.
Responsibility for the contents resides in the author or organisation that prepared it.

		Company:	Signature:	Date:
Prepared by :	D. VRANCKEN	QINETIQ SPACE		
Checked by :	D. GERRITS	QINETIQ SPACE		
Approved by :	L. BIERQUE	QINETIQ SPACE		
Prod. Ass.:	T. DEBRAEKELEER	QINETIQ SPACE		
Proj. Man.	D. VRANCKEN	QINETIQ SPACE		

Customer approval:

□ Please insert revised page(s) and remove old page(s)
X Re-issued document, distributed in its entirety

DISTRIBUTION LIST

Quantity	Company	Department	Name
2	ESA		M. SNAAYER
1	QINETIQ SPACE		ARCHIVE

CHANGE RECORD

Iss.	Rev.	Date	# Pages	affected P.	Description
A	0	21/02/2009	IX+14	All	First issue
B	0	23/03/2009	IV+14	All	Compliance matrix updated
C	0	30/06/2009	IV+15		Update for PDR
				16	A waiver request on Requirement OR-01 is added in Appendix E.
D	0	14/07/09	IV+16	16	Signed waiver request by ESA-DG is added in the appendix.
E	0	29/03/10	IV+15	2	Update for CDR, update of the applicable documents
F	0	30/01/13	IV+16	all	Update for FAR
G	0	18/02/13	IV+16	10, 15	Updated casualty risk analysis

Documentation control procedure:
Changes to the present document will be sent to all registered recipients (all persons on the distribution list).
Text amendments with respect to the previous issue are identified by a vertical bar in the right margin. Minor text amendments like underlining, punctuation, spelling, page numbers and deletions are not marked however.

TABLE OF CONTENTS

LIST OF ABBREVIATIONS

The complete list of PROBA-V abbreviations is given in PROBAV-LI-00207-VE.

1. SCOPE

The scope of this document is to formulate and respond to “the requirements for space debris mitigation” for ESA projects. [AD 8]
This document primarily deals with the list of compliance and non-compliances with respect to space debris mitigation requirements and it includes a description of design and operational measures.

PROBA-V does not include on-board propulsion therefore any requirements relating to propulsion are not relevant to this mission.
For example the following manoeuvres shall not be performed on PROBA-V.

1) De-orbiting at EOL and
2) Collision avoidance.

2. DOCUMENTS

2.1 APPLICABLE DOCUMENTS

The following documents are to be considered as applicable to the extent specified within.

AD	Doc Nr	Issue/ Rev.	Title
AD-1	RFQ NO.: 3-12558/08/NL/GLC	3/1	PROBA Vegetation Statement of Work
AD-2	PV-RS-ESA-SY-0001	3/0 Draft	Mission Requirements Document (MRD)
AD-3	PV-RS-ESA-SY-0002	3/0 Draft	System Requirements Document (SRD)
AD-4	PV-RS-ESA-SY-0003	1/0	PROBA-V PA Requirements + Amended PA Requirements
AD-5	PV-RS-ESA-SY-0004	2/0	PROBA-V Management Requirements Document
AD-6	PV-LI-ESA-SY-0002	2/0	PROBA-V Document Requirement List and Document Requirement Description
AD-7	PV-LI-ESA-LI-0001	2/0	ECSS E Applicability to PROBA-V
AD-8	ESA/ADMIN/IPOL 2 ANNEX 2	2008	Requirements on Space Debris Mitigation for ESA projects
AD-9	PROBAV-PL-00036-VE	E/0	PROBA-V Product Assurance and Safety Plan
AD-10	PROBAV-PL-00047-VE	A/0	PROBA-V Configuration Management and Control Plan
AD-11	PROBAV-SP-00651-VE	D/1	Generic Equipment Requirements Specification
AD-12	PROBAV-LI-00686-VE	A/0	ECSS List of applicability
AD-13	PROBAV-TN-00159-VE	D/1	Definition of reference frames and control errors
AD-14	PROBAV-SP-00085-VE	D/0	Reaction wheels unit requirements
AD-15	PROBAV-SP-00235-VE	C/0	Magnetotorquer unit requirements
AD-16	PROBAV-SP-00236-VE	C/0	Magnetometer unit requirements
AD-17	PROBAV-SP-00238-VE	D/0	GPS receiver unit requirements
AD-18	PROBAV-SP-00239-VE	C/0	GPS antenna unit requirements
AD-19	PROBAV-SP-00240-VE	C/0	Star tracker unit requirements
AD-20	PROBAV-SP-00237-VE	C/0	AIE unit requirements
AD-21	PROBAV-SP-00087-VE	E/1	AOCS SW requirement specification

AD	Doc Nr	Issue/ Rev.	Title
AD-22	PROBAV-SP-00233-VE	D/0	S-band antenna unit requirements
AD-23	PROBAV-SP-00214-VE	D/1	S-band transceiver unit requirements
AD-24	PROBAV-SP-00243-VE	C/0	X-band antenna unit requirements
AD-25	PROBAV-SP-00215-VE	C/2	Battery unit requirements
AD-26	PROBAV-SP-00224-VE	E/1	Photo Voltaic Assembly unit requirements
AD-27	PROBAV-SP-00275-VE	C/3	Specific ADPMS requirements
AD-28	PROBAV-SP-00766-VE	C/0	Specific reaction wheels power supply requirements
AD-29	PROBAV-SP-00091-VE	A/0	Satellite harness specification
AD-30	PROBAV-RP-00273-VE	F/0	CDMS use cases
AD-31	PROBAV-SP-00242-VE	C/0	System requirements specification
AD-32	PROBAV-ICD-00126-VE	F/0	Vegetation instrument requirements

2.2 REFERENCE DOCUMENTS

RD	Doc Nr	Issue Date	Revision	Title
1	PROBAV-RP-00077-A4-VE	30/06/09	C/0	Mission analysis report
2	Space Mission Analysis and Design	1999	-	Space Mission Analysis and Design
3	In-house Matlab Tool	04/2009	1.1	In-house Matlab tool to perform Mission analysis.
4	DAS 2.0.1	05/2008	2.0.1	Debris Assessment Software, NASA, R. O'Hara, M. Matney and P. Anz-Meador.

3. INTRODUCTION

The PROBA-V (PRoject for On Board Autonomy-Vegetation) mission architecture is based on the PROBA Platform carrying the Vegetation instrument as the main payload. The PROBA-V Platform is a small satellite platform of about 160 kg with a size of 800x800x1000 mm^3.

The PROBA-V satellite is targeted to be launched by early 2013 as primary passenger of the VEGA launcher; it will be placed directly into its operational orbit, with an altitude of 820 km. The Flight segment is designed to operate for 2 and ½ years in-orbit with the possibility to extend the mission life time up to 5 years.

PROBA-V is an ESA project and should comply with the European code of conduct for space debris mitigation. In the next chapter, the requirements of Space Debris Mitigation are specified w.r.t PROBA-V.
Director General of ESA shall specifically approve all requirements, when Partial Compliance (PC) or Non Compliance (NC) are stated.

4. SPACE DEBRIS MITIGATION REQUIREMENTS

General space debris mitigation requirements for the PROBA-V mission are extracted in Table 4.1, Table 4.2 and Table 4.3. They include management requirements, design requirements and operating requirements, respectively.

Table 4.1: Space debris mitigation- Management requirements

No#	REQUIREMENTS	C	PC	NC	Comments
	MANAGEMENT REQUIREMENTS				
MR-01	The prime contactor of the space project shall be responsible for the implementation of space debris mitigation measures as defined in this document. The prime contractor shall deal with these requirements using the same engineering methodology and the same reporting as for all other contractually applicable Agency requirements.	X			
MR-02	In order to implement the space debris mitigation measures defined in this document the space project prime contractor shall: a) define derived design requirement specifications at system and sub-system level; b) verify compliance with the design requirements; c) define and verify necessary operational procedures prior to launch; d) document activities and procedures resulting from a, b, and c.	X			
MR-03	Verification of and compliance with the applicable space debris mitigation requirements shall be reported by the space project prime contractor as part of the overall space project verification control up to Flight Acceptance Review.	X			
MR-04	The space project prime contractor shall document in a “Space Debris Mitigation Document” the measures put in place to implement and fulfil the applicable requirements. The document shall be part of the Design Justification File.	X			
MR-05	The Space Debris Mitigation Document shall: a) be provided for and reviewed at the space project System Requirements Review; b) be updated for and reviewed at the space project Preliminary Design Review; c) be updated and revised by the space project prime contractor to follow the design evolution of the space project; d) be updated for and reviewed at the space project Critical Design Review.	X			

MR-06	The Space Debris Mitigation Document shall contain as a minimum: a) a table of compliance with the requirements in the present document; b) a description of design and operational measures put in place to achieve compliance; c) a list of objects (mission-related objects or space debris) released as part of the nominal mission. For these objects, the physical characteristics, the orbital characteristics and the predicted on-orbit lifetime shall be provided; d) a feared-events list of malfunctions of the space system which have the potential to cause space debris, and a description of the characteristics of the debris so caused.	X			

Table 4.2: Space debris mitigation - Design requirements [AD 8]

No#	REQUIREMENTS	C	PC	NC	Comments
	DESIGN REQUIREMENTS				
DR-01	a) For the launch of a single payload there shall be at most one additional launch vehicle element (for example the insertion stage) injected into orbit. b) For the launch of multiple payloads there shall be at most two additional launch vehicle elements (for example the insertion stage and an adaptation structure for multiple payloads) injected into orbit.	N/A			To be justified by the launcher authorities. Launch is not directly procured by the PROBA-V project.
DR-02	Spacecraft shall be designed such that objects that must be released as part of the nominal mission are retained and do not become detached from the spacecraft. In cases where this is not possible for technical or operational reasons the following requirements apply: a) mission-related objects and space debris so generated shall remain outside the GEO protected region b) mission-related objects and space debris so generated shall not remain in the LEO protected region for more than 25 years after their release; c) a justification for the implementation shall be given in the space debris mitigation document	X			Point (a) is not applicable to PROBA-V Point (b) compliant; no objects released from the PROBA-V S/C. Point (c) No debris is released from the PROBA-V.
DR-03	A space system or any of its parts shall not be intentionally destroyed in orbit.	X			No destruction mechanism is implemented on the S/C.
DR-04	Solid rocket motors releasing burn products larger than 1mm into orbit shall not be used.	X			No solid propellants are used on PROBA-V
DR-05	The use of pyrotechnics (for example, pyrotechnic cutters) shall not release into orbit any particles greater than 1 mm.	X			No pyrotechnics present on PROBA-V
DR-06	The system shall be designed such that the end-of-life measures shall be fulfilled by the operator.	X			Only end-of-life passivation
DR-07	An analysis shall be performed to determine and allocate the amount of propellant needed to perform the required end-of-life manoeuvres.	X			Analysis has been performed and is shown in APPENDIX B: Design requirements- Deorbiting. However, no propulsion system is implemented on the PROBA-V S/C
DR-08	The design shall allow the operator to establish the propellant reserve with accuracy, which is compatible with performing the end-of-life manoeuvres.	N/A			Not applicable, since there is no onboard propulsion to comply with accuracy and EOL manoeuvres.
DR-09	Space system shall be designed such that it can be permanently passivated at the end of its disposal phase.	C			End-of-life passivation operations are

					described in the 'Specific Operations Document' PROBAV-TN-05177-QS_B0 section 16.
DR-10	The reliability of successfully performing the end-of-life disposal and/or passivation shall not be less than the nominal mission reliability for the operational phase.	C			

Table 4.3: Space debris mitigation - Operational requirements [AD 8]

No#	REQUIREMENTS	C	PC	NC	Comments
	OPERATIONAL REQUIREMENTS				
OR-01	Space systems operating in the LEO protected region shall be disposed of by re-entry into the Earth's atmosphere within 25 years after the end of the operational phase.			X	Non compliance as there is no onboard propulsion system. See APPENDIX C: Operational requirments-End of life measures **A waiver has been generated by ESA [APPENDIX E: Waiver- Requirement "OR-1"].**
OR-02	Space systems operating in the GEO protected region shall be disposed of by permanently removing them from the GEO protected region.	N/A			PROBA-V is a LEO satellite.
OR-03	Where practicable and economically feasible, space systems outside the LEO and GEO protected regions shall implement means of end-of-life orbit disposal to avoid long-term interference with operational orbit regions, such as the Galileo orbit.	N/A			N/A, as PROBA-V is a LEO satellite.
OR-04	Launcher stages shall satisfy one of the following conditions: a) they shall perform a direct re-entry as part of the launcher sequence; b) they shall be placed in a LEO orbit where they will re-enter the Earth's atmosphere within 25 years; c) they shall be permanently removed from the LEO and GEO protected regions, and from orbits interfering with other operational orbit regions, such as the Galileo orbit.	N/A			To be justified by the launcher authorities. Launch is not directly procured by the PROBA-V project.
OR-05	Passivation of a space system shall be completed within two months after the end of the operational phase. This includes launcher stages which remain in orbit.	C			Compliant for End-of-Life passivation. For launcher stages: to be justified by the launcher authorities. Launch is not directly procured by the PROBA-V project.

OR-06	For space systems that are disposed of by re-entry, the prime contractor shall perform an analysis to determine the characteristics of fragments surviving to ground impact, and assess the total casualty risk to the population on ground assuming an uncontrolled re-entry.	X			Casualty risk is 1:11700 see [APPENDIX D: Re-entry analysis]

Terms and definitions related to the space debris requirements are in APPENDIX A: Terms and definitions

5. CONCLUSION

PROBA-V is a mini satellite with a maximum size of 1000 x 800 x 800 mm³. The orbit drift analysis [RD 1] showed that there is no on-board propulsion system needed for orbit correction and maintenance, in case the spacecraft is injected into a quasi SSO. Thus, propulsion on-board has not been considered and PROBA-V shall remain in orbit after EOL. End-of-Life passivation operations have been defined.

Passivation of the launch vehicle stages is a concern to launch authorities. It shall be performed by the relevant launch authority. The launch is not directly procured by the PROBA-V project.

All requirements are compliant except OR-01, for which ESA-Project has introduced a waiver, which is in Appendix .

APPENDIX A: TERMS AND DEFINITIONS

Terms and definitions used in the document to represent requirements are:

1. Disposal Phase: Begins at the end of the operational phase of the Space System and ends when either the Space System has performed a direct re-entry or completed its disposal activities (having reached its disposal orbit and having completed its passivation).
2. End of Life: End of the disposal phase.
3. LEO: Low Earth Orbit, with an altitude below 2000 km.
4. Mission-Related Objects: Protection or adaptor structures or mechanisms required for the deployment of one or several payloads into orbit.
5. Operational Phase: The period during which a space system performs its useful function.
6. Orbital Lifetime: The length of time that a space system remains in orbit.
7. Passivation: The elimination of all stored energy on-board of a space system.
8. Space System: Spacecraft, launch vehicle stages, and mission-related objects.
9. Space Debris: Any man-made space object, including fragments and elements thereof, in Earth orbit or re-entering the Earth’s atmosphere that is non-functional.

APPENDIX B: DESIGN REQUIREMENTS- DEORBITING

According to the space debris mitigation [AD 8], a satellite in a LEO should either re-enter in the earth's atmosphere or be disposed at an altitude of less than 600km or greater than 2500 km. As, PROBA-V is at an altitude of 820 km, de-orbiting to 600 km is less expensive than boosting the satellite to 2500 km.

A single long retro thrust manoeuvre or a high impulse retro thrust manoeuvre at apogee results in a decreased perigee altitude, thus a set of manoeuvres can bring the perigee of the satellite to an altitude of 550-600 km, causing more atmospheric drag on the satellite. This is shown in Figure A.0.1. The final orbit, after de-orbiting shall be an elliptical orbit with apogee at 820 km and perigee at 600km.

Delta-V required in this strategy is given by: [RD 2]

$$\Delta V_{deorbit} = V \cdot \left(1 - \sqrt{\frac{2 \cdot (\mathrm{Re} + H_{deorbit})}{(\mathrm{Re} + H_{deorbit}) + r}}\right) \qquad (0.1)$$

Where, V is velocity of initial orbit in m/s,
r is the radius of the initial orbit in km,
R_e is the radius of the Earth, 6378 km
$H_{deorbit}$ = Altitude of the de-orbiting orbit.

Table A.0.1 summarizes the delta-V required to de-orbit PROBA-V to various altitudes:

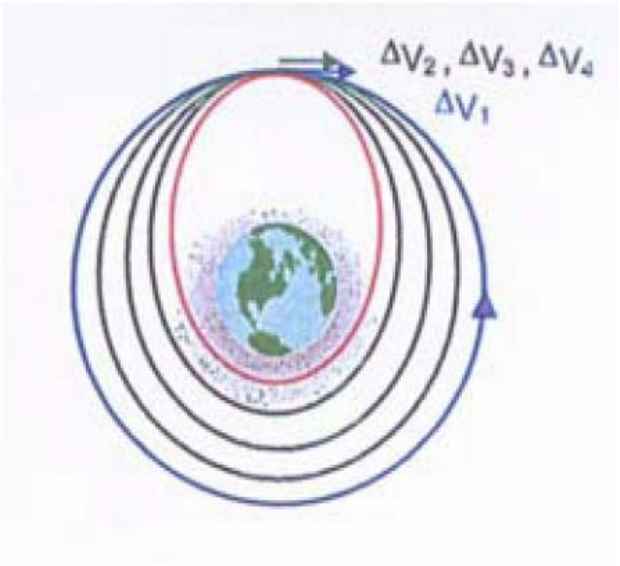

Figure A.0.1: Multiple apogee burn strategy

Table A.0.1: Delta-V de-orbiting

H [km]	$H_{deorbit}$ [km]	Delta-V [m/s]
820	600	57.84
820	590	60.54
820	580	63.24
820	570	65.95
820	560	68.66
820	550	71.38

Therefore, with a margin of 20%, the total delta-V required to de-orbit to 600km is 69.4m/s.

APPENDIX C: OPERATIONAL REQUIRMENTS-END OF LIFE MEASURES

According to the European Code of Conduct for Space Debris Mitigation [AD 8] spacecraft in LEO should be de-orbited, i.e. allowed to fall into the atmosphere and burn up, within 25 years of the end of the mission. In other words, the spacecraft should de-orbit to an altitude range of 550 km-600 km at End Of Life (EOL).

As there is no propulsion on PROBA-V, natural decay of orbit from 820 km is more than 250 years. Hence the spacecraft is non-compliant to the requirement OR-03 of "European Code Of Conduct For Space Debris Mitigation". [AD 8].

Natural decay of PROBA-V from an altitude of 820 km is shown in Figure A.0.1

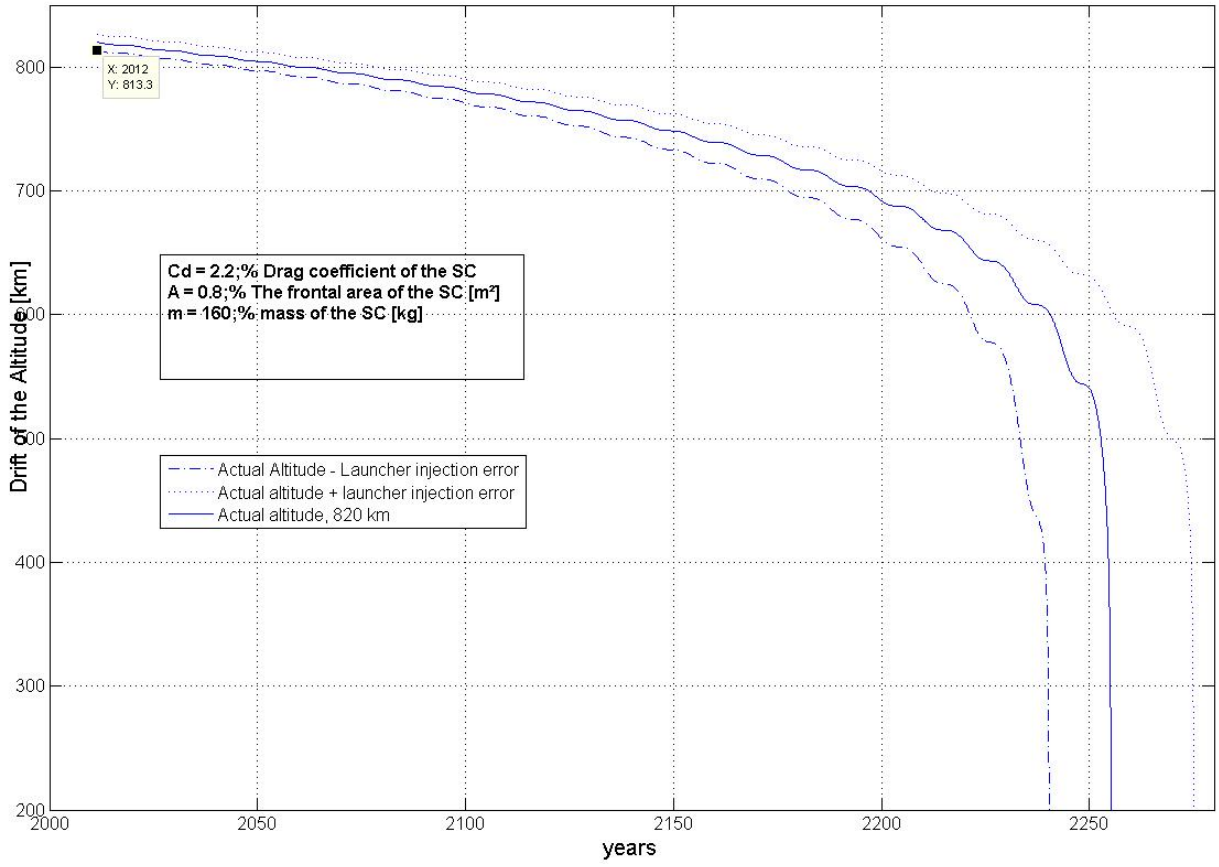

Figure A.0.1: Natural decay of PROBA-V from 820 km for 200 years [RD 3]

APPENDIX D: RE-ENTRY ANALYSIS

A re-entry analysis has been performed using the “DAS 2.0” (Debris Assessment Software) software. The results are shown in the table below.

A casualty risk of 1:11.700 is obtained, which is smaller than the requirement of 1:10.000. The PROBA-V satellite is as such compliant with the requirements.

Reentry Data														
Row Num	Name	Parent	Qty	Material	Body Type	Thermal Mass	Diameter/Width	Length	Height	Status	Risk	Demise Alt	Total DCA	KE
1	PROBA-V	0	1	Aluminum (generic)	Box	145	0.7	0.834	0.68	Compliant	'1:11700'		6.65	
2	Bottom Board	1	1	Aluminum (generic)	Flat Plate	12.63	0.65	0.68				68.3	0.00	0
3	Bus panel	2	1	Aluminum (generic)	Flat Plate	13.92	0.61	0.8				58.6	0.00	0
4	AIE	3	1	Aluminum (generic)	Box	3.38	0.2	0.3	0.1			0.0	0.66	2650
5	S-band transceiver	3	1	Aluminum (generic)	Box	6.22	0.187	0.257	0.13			0.0	0.64	9378
6	X-band transmitters	3	3	Aluminum (generic)	Box	1.02	0.115	0.16	0.046			0.0	1.53	826
7	Magneto-torquers	3	1	Iron	Cylinder	0.24	0.014	0.325				0.0	0.45	140
8	ADPMS	3	1	Aluminum (generic)	Box	15.4	0.218	0.444	0.212			0.0	0.83	30483
9	Harness	3	1	Copper Alloy	Cylinder	5.7	0.02	3				54.4	0.00	0
10	Central panel	2	1	Aluminum (generic)	Flat Plate	1.75	0.23	0.8				66.3	0.00	0
11	Reaction wheels	10	4	Aluminum (generic)	Box	0.75	0.1	0.105	0.07			59.8	0.00	0
12	EPT	10	1	Aluminum (generic)	Box	4.57	0.129	0.242	0.125			51.9	0.00	0
13	Battery	10	1	Aluminum (generic)	Box	3.48	0.15	0.2	0.095			48.0	0.00	0
14	Payload panel	2	1	Aluminum (generic)	Flat Plate	6.05	0.61	0.8				64.6	0.00	0
15	VI + radiator + Star Tracker	14	1	Aluminum (generic)	Box	25.52	0.5	0.8	0.2			0.0	1.27	25096
16	PSU	14	1	Aluminum (generic)	Box	3.1	0.2	0.2	0.2			0.0	0.64	1813
17	DHU	14	1	Aluminum (generic)	Box	2	0.2	0.25	0.1			0.0	0.63	1021
18	ROEs	14	3	Aluminum (generic)	Box	1.2	0.136	0.180	0.04			51.9	0.00	0
19	ADS-B elec	14	1	Aluminum (generic)	Box	1	0.140	0.170	0.06			56.0	0.00	0
20	ST DPU	14	1	Aluminum (generic)	Box	0.64	0.1	0.112	0.04			56.5	0.00	0
21	Harness	14	1	Copper Alloy	Cylinder	2.12	0.02	2				62.8	0.00	0
22	Flexible Fingers	2	6	Steel A-286	Box	0.4	0.025	0.1	0.025			62.3	0.00	0
23	S-band antenna	2	1	Aluminum (generic)	Cylinder	0.4	0.06	0.07				63.5	0.00	0
24	GPS antenna	2	2	Aluminum (generic)	Cylinder	0.33	0.089	0.03				64.5	0.00	0
25	Satram	2	1	Aluminum (generic)	Box	0.38	0.05	0.1	0.05			65.0	0.00	0
26	Top panel	1	1	Aluminum (generic)	Flat Plate	3.15	0.61	0.61				74.5	0.00	0
27	Flexible fingers	26	8	Steel A-286	Box	0.4	0.025	0.1	0.025			62.9	0.00	0
28	Magnetotorquers	26	2	Iron	Cylinder	0.24	0.014	0.325				66.0	0.00	0
29	Hermod	26	1	Aluminum (generic)	Box	0.9	0.115	0.16	0.046			66.1	0.00	0
30	X-band antennas	26	3	Aluminum (generic)	Cylinder	0.44	0.05	0.2				69.5	0.00	0
31	S-band antenna	26	1	Aluminum (generic)	Cylinder	0.4	0.06	0.07				65.7	0.00	0
32	Nadir panel	1	1	Aluminum (generic)	Flat Plate	2.3	0.475	0.820				75.3	0.00	0
33	ADS-B antenna	32	2	Aluminum (generic)	Flat Plate	0.19	0.1	0.1				66.5	0.00	0
34	LRR	32	1	Aluminum (generic)	Cylinder	0.33	0.15	0.05				69.3	0.00	0
35	Velocity Panel	1	1	Graphite Epoxy 1	Flat Plate	3.95	0.764	0.834				77.4	0.00	0
36	Zenith Panel	1	1	Graphite Epoxy 1	Flat Plate	3.75	0.68	0.834				77.4	0.00	0
37	Anti-Velocity Panel	1	1	Graphite Epoxy 1	Flat Plate	3.70	0.68	0.834				77.4	0.00	0

APPENDIX E: WAIVER- REQUIREMENT "OR-1"

esa PROBA-V

Doc. No.: PV-RFW-ESA-001
Revision: 0
Date: 23 March 2009
Page: 1 of 2

REQUEST FOR WAIVER (RFW)

(3) Title of Waiver: PROBA-V Disposed by re-entry within 25 Years not possible			(5) Reason for Waiver: The present design of the PROBA-V Spacecraft, i.e. including no propulsion, does not allow the re-enter of the satellite within 25 years after the end of the mission's operational phase.
(4) Initiator-Org.: ESA	(4a) Initiator-Name: K. Mellab	(6) Production affected: ( ) YES (X) NO	
(7) Item affected: PROBA-V Spacecraft	(8) C.I. affected N/A	(9) Model/Version PFM	(10) Serial # 01
(11) ROMT, Document affected			
Doc. Number: Admin-ipol-2008-002E	Issue/Rev.: -	Document Title: Space Debris Mitigation for Agency Project	Paragraph(s)/reqmt. ID: Annex 1/OR-01
(12) Other related documents affected: N/A			
Doc. Number:	Issue/Rev.:	Document Title:	Paragraph(s)/reqmt. ID:
(13) Similar Previous RFW N/A	(14) RFW affects: N/A		(15) Class of RFW

(16) Details:

The PROBA-V satellite baseline design does not include a propulsion subsystem and is hence not capable to perform the orbital manoeuvre necessary to re-enter at the end of the Vegetation mission, as requested by ESA Admin-ipol-2008-002E requirement OR-01.

The PROBA-V orbital parameters are:

- Circular quasi Sun Synchronous orbit with 820 km altitude and ~99 degrees inclination,
- Local Time at Descending Node (LTDN) between 10:30 and 11:30, taking into account the orbital drift during mission lifetime.

Natural orbit decay predictions from the above orbit indicate that the satellite will not re-enter the Earth atmosphere before 250 years after end of its operational mission phase. (see in annex the prediction curve of the natural decay for the first 100 years).

(17) Justification:

This Request for Waiver is justified in view of the following elements:

- Heritage of the PROBA-1 and PROBA-2 platforms.
- The PROBA_V simplified design, i.e. without propulsion, guarantees the containment of loose items and avoid risk of explosion.
- The challenging project schedule and the associated risk linked with the implementation of a propulsion subsystem on a recurring platform not designed for this purpose,
- The fact that the PROBA-Vegetation mission objectives can be fulfilled without the need for orbital maintenance,
- The increase of the platform's mass (>15%) and volume (>15%) required to perform orbital manoeuvres to re-enter the satellite from an altitude of 820km (about 100m/s required ΔV),
- The increase of mass and volume jeopardizes the possibility to identify a launch as piggyback passenger.

All other requirements from ESA Admin-ipol-2008-002E remain applicable to PROBA-V and fulfilled by the design of the flight segment.

Project	System Engineer S.Santandrea (TEC-SY)	Product Assurance	Project Manager K.Mellab (TES-SYV) F.Teston (TEC-SY)	Disposition Approved
ESA	M.Counotte (D/TEC) 27.4.09	J.Bosma (TEC-Q)	J.J.Dordain (DG) 30/04	Disposition