GRACE 327-720
(CSR-GR-03-02)

Gravity Recovery and Climate Experiment

Product Specification Document

(Rev 4.6 – May 29, 2012)

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DOCUMENT CHANGE RECORD

Issue	Date	Pages	Change Description
Draft	Nov 4, 1999	All	Initial Version
Issue 1.0	Nov 23, 2000	All	- Ch I: Updated frame definitions & rotations - Ch II: Listed references from Level-0 data to TM application packets - All Chapters: Updated data rates, definitions & formats
Issue 2.0	Oct 29, 2001	All	- Ch I : Updated frame definitions. Added satellite nomenclature & thruster information - Ch II : Moved AppPkt definition to Appendix I - Ch III-V : Updated product nomenclature.
Issue 3.0	Feb 18, 2002	All	I.4: Updated Product Summary I.5.1.1-2: Updated time system reckoning I.5.2.3: Updated SCA head orientations I.5.4: Added Satellite Macro Model Ch II-V: Updated product nomenclature, data rates & formats specifications Ch IV: All Level-1B flight data latencies changed to ≈ 12 days
Issue 4.0	Dec 1, 2003	All	Header – introduced creating center (UTCSR) document number into header I.4: Altered Level-1B alignment products to start with prefix Q and vectors to start with V. Altered Level-2 products nomenclature consistent with Chapter V. I.5.2: Introduced Science Reference Frame (SRF) - also introduced K-Frame - Clarified the frame of specification of Level-1B products as the SRF I.5.3.6: Updated SLR antenna location I.5.3.8: Deleted section on definition of spherical harmonics I.5.4: Inserted section of “related documents” Ch III: Updated data rates & file contents Ch. IV: Replaced references to “Accelerometer Frame” by “Science Reference Frame” – where appropriate. IV.5: Corrected definitions to alignment products. Ch V: Replaced entire chapter to bring it to consistency with the *Level-2 Product User Handbook*.

Issue 4.1	Jan 9, 2004		I.3 & Ch III-V: Updated (ascii-gzipped) data volume entries for all products. I.5.1.1 – Changed GPS-KBR synchronization from 70 to 50 ps. I.5.3.6 – Noted that specified values include the correction to LRR.
Issue 4.2	Aug 2, 2004	23 56, 58, 59	Added note on L1/L2 phase centers IV.5.5, 7, 8 – Added mention of L1 & L2 phase centers
Issue 4.3	Apr 25, 2006	63-64	Made V.2 compatible with L-2 User Handbook (GRACE 327-734)
Issue 4.4	Feb 14, 2007	23	Clarified remarks on GPS phase center offset.
		64-65	Made V.2 compatible with L-2 User Handbook (GRACE 327-734)
Issue 4.5	Feb 20, 2007	23	In Section I.5.3.6, replaced antenna mechanical offsets with pointers to Level-1B products that contain the precise values recommended for use.
Issue 4.6	May 29,2012	23	Antenna location filename updated

TABLE OF CONTENTS

I INTRODUCTION

I. 1 SCOPE OF DOCUMENT

This document provides a detailed description of data products at all levels for the Gravity Recovery And Climate Experiment (GRACE) Mission. The data products specified in this document are obtained from the science instruments and subsystems on board the twin GRACE spacecrafts, and include the results of any ground data processing carried out by the GRACE Science Data System (SDS).

At all levels of science data processing, several additional data are also needed. These may include the results of pre-flight tests or calibration experiments carried out by the GRACE project. Further, certain science data are collected by various terrestrial observatories specifically for the GRACE mission, and are acquired by the GRACE SDS through existing, independent data systems outside the GRACE project. Other ancillary data (independent of the on-board measurements) are generated by the GRACE SDS itself. All of these data products are specified in this document. However, standard data products (e.g. products available from the IGS or IERS), commonly available to the science community and independently documented, are not specified in this document.

This document is consistent with, and responsive to

- GRACE Science Data System Development Plan (GRACE 327-710);
- Science & Mission Requirements Document (GRACE 327-200).

Other applicable documents include

- GRACE Satellite System Specification (GRACE 327-400)
- SuperSTAR Accelerometer Specification (GRACE 327-520)
- Instrument Processing Unit Specification (GRACE 327-540)
- Star Camera Specification (GRACE 327-530)
- On-Board Software Data Interfaces & Data Flow Document (GR-DJO-SW-0005)
- Level-1 User Handbook (GRACE 327-733)
- Level-2 User Handbook (GRACE 327-734)
- Level-2 Formats Document (GRACE 327-732)

The Product Specification Document is a "living" document. With the increasing maturity of the Science Data System, as well as other GRACE project systems, the information contained here is expected to evolve further. At suitable intervals, updated versions of this document will be released.

I. 2 GRACE SCIENCE DATA SYSTEM

I.2.1 SDS Overview

The GRACE SDS is a distributed system. System development, data processing and archival is shared between the Jet Propulsion Laboratory (JPL), The University of Texas Center for Space Research (UTCSR) and the GeoForschungsZentrum Potsdam (GFZ). The SDS is designed to perform all tasks for gravity field processing through the production of the monthly and mean gravity field models, in accordance with the GRACE SDS Development Plan (327-710), and the SMRD (327-200).

The general data flow for the GRACE mission is presented in Figure I-1, with the SDS components shaded.

In general, all science data are collected on-board continuously during the mission. The exception to this is the GPS radio occultation data, which will be gathered to provide approximate 200 to 250 profiles per day. The duration of each profile depends on the rise and set geometry of the GPS satellite relative to the GRACE satellites. The housekeeping data, on the other hand, is collected as available, depending on the operating modes of the satellite.

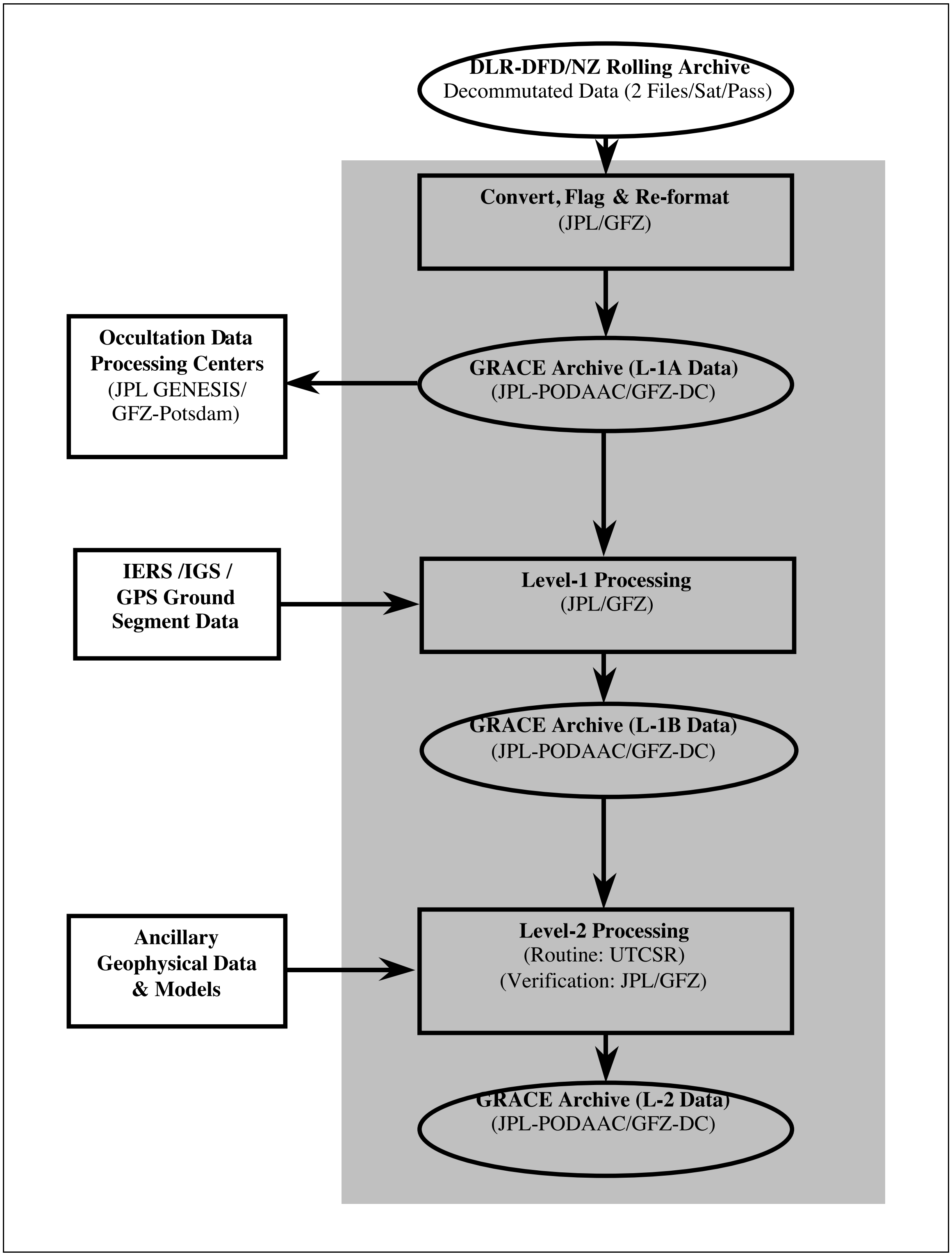

Figure I-1 GRACE Science Data Flow (Shaded areas denote the SDS)

I.2.2 Level-0 Data Products

The Level-0 data products are the result of telemetry data reception, collection and decommutation by the GRACE Raw Data Center (RDC) at DLR in Neustrelitz. This telemetry data from each down-link pass is separated into the Science Instrument and Spacecraft Housekeeping data streams, and placed in a rolling archive at the RDC. From each satellite, as a result, two files from each pass are made available in the rolling archive. These two files are defined to be the Level-0 Data Products.

The GRACE SDS acquires these data from the rolling archive at RDC, and stores them in permanent archives at the SDS centers at JPL and GFZ. Each Level-0 data product file contains, besides the appropriate headers, the un-scaled, binary encoded instrument communication packets. These individual data packets are described in detail in the respective instrument and spacecraft specification documents, but a few of them are also included here for completeness. The description of the instrument data packets in this document is secondary, and does not supersede their descriptions in the applicable instrument specification documents.

I.2.3 Level-1A Data Products

The Level-1A Data Products are the result of a non-destructive processing applied to the Level-0 data. The sensor calibration factors are applied in order to convert the binary encoded measurements to engineering units. Where necessary, time tag integer second ambiguity is resolved and data are time tagged to the respective satellite receiver clock time. Editing and quality control flags are added, and the data is reformatted for further processing. The Level-1A data are reversible to Level-0, except for the bad data packets. This level also includes the ancillary data products needed for processing to the next data level.

I.2.4 Level-1B Data Products

The Level-1B Data Products are the result of a possibly destructive, or irreversible, processing applied to both the Level-1A and Level-0 data. The data are correctly time-tagged, and data sample rate is reduced from the higher rates of the previous levels. Collectively, the processing from Level-0 to Level-1B is called the Level-1 Processing. This level also includes the ancillary data products generated during this processing, and the additional data needed for further processing.

I.2.5 Level-2 Data Products

The Level-2 data products include the gravity field and related data products derived from the application of Level-2 processing to the previous level data products. This level also includes the ancillary data products generated during this processing.

I. 3 Product Notation

Each data product is labeled with a product identifier. For each product, certain characteristic attributes are described in later chapters. This section defines the product identifier and the product attributes. The product identifier, in conjunction with either a date or a range of dates in a specified format determines the filename containing the data product.

Product Identifier & associated filename	**XXXLL_(DATE)_S_RL** Where, **XXX**: is a product mnemonic **LL**: specifies the data product level (00, 1A, 1B or -2). **S**: If satellite specific, it is one of A or B; X otherwise. **RL**: Specifies the Release number (00, 01, 02, …) The **(DATE)** field (without parentheses) determines the unique filename which contains the data for that date. This field is specified in the format *YYYY-MM-DD*. Exceptions to this nomenclature are noted in relevant sections.
Product Definition	A verbal, precise and unambiguous description of the information content of the data product.
Representation	Description of how the data is represented, if it is not directly measured, or is defined relative to either other constants or other data.
Units	Units of the data product
System	If applicable, the reference system
Resolution	The temporal or spatial resolution of the product. If applicable, also specifies the span in time or space for which the product is defined.
Inputs	Products from which this data product was derived (immediately previous set)
Data Volume	Quantity of data product in megabytes per day (ascii-gzipped)
Data Format	Special remarks on data packaging or formatting.
Latency	Elapsed time since the date of availability of the last data used in generating this product.
Notes	Descriptive, Explanatory or Processing notes as appropriate

I. 4 DATA PRODUCT SUMMARY

In this section, a summary of the all the data products, including the product identifiers, is given for reference.

Source	XXX	LL	S	Definition
IPU	GPS	1A	A/B	GPS Flight Receiver Data (III.2.1)
	GNV	1A	A/B	GRACE On-Board Orbit (III.2.2)
	CLK	1A	A/B	Smoothed On-Board Clk Sol (III.2.3)
	KBR	1A	A/B	K-Band Ranging Data (III.2.4)
	SCA	1A	A/B	Star Camera Data (III.2.5)
	IHK	1A	A/B	IPU Housekeping Data (III.2.6)
ACC	ACC	1A	A/B	Accelerometer Science Data (III.3.1)
	AHK	1A	A/B	Accmtr Housekeeping Data (III.3.2)
Satellite h/k & Others	TIM	1A	A/B	OBDH to GPS Time Mapping (III.4.1)
	MAG	1A	A/B	Magmtr & Mtq Data (III.4.2)
	THR	1A	A/B	Thruster Activation Data (III.4.3)
	TNK	1A	A/B	Tank Sensor Information (III.4.4)
	MAS	1A	A/B	Satellite Mass Data (III.4.5)
IPU	GPS	1B	A/B	GPS Flight Receiver Data (IV.2.1)
	GNV	1B	A/B	GRACE Orbit Solution (IV.2.2)
	CLK	1B	A/B	Precise Clock Solution (IV.2.3)
	USO	1B	A/B	USO Frequency Estimate (IV.2.4)
	KBR	1B	X	Dual-One-Way Ranging Data (IV.2.5)
	SCA	1B	A/B	Star Camera Solution (IV.2.6)
	IHK	1B	A/B	IPU Housekeeping Data (IV.2.7)
ACC	ACC	1B	A/B	Acceleration Data (IV.3.1)
	AHK	1B	A/B	Acc Housekeeping Data (IV.3.2)
Satellite House-Keeping	MAG	1B	A/B	Mag & Mtq Data (IV.4.1)
	THR	1B	A/B	Thruster Activation Data (IV.4.2)
	TNK	1B	A/B	Tank Sensor Information (IV.4.3)
	MAS	1B	A/B	Spacecraft Mass Data (IV.4.4)
	TIM	1B	A/B	OBDH to GPS-Time Map. (IV.4.5)
A-Priori Models	AOD	1B	X	Atm-Ocean Gravity Model (IV.5.10)
	OCN	1B	X	Ocean Pressure Model (IV.5.11)
Ground Analysis or Meas.	QSA	1B	A/B	SCHeads Orient. wrt SRF (IV.5.1)
	QSB	1B	A/B	Sat Frame Orient wrt SRF (IV.5.2)
	QKS	1B	A/B	SCHeads Orient. wrt K-Frame (IV.5.3)
	VCM	1B	A/B	CoMass Offset Estimate (IV.5.4)
	VGN	1B	A/B	GPS Nav Antenna Offset (IV.5.5)
	VKB	1B	A/B	K-Band Antenna Offset (IV.5.6)

	VGO	1B	A/B	GPS Occ Antenna Offset (IV.5.7)
	VGB	1B	A/B	GPS Bkup Antenna Offset (IV.5.8)
	VSL	1B	A/B	SLR Reflector Offset (IV.5.9)
Level-2 Analysis	*xxx*	-2	A/B	See V. 2 for Level-2 product nomenclature & attributes

I. 5 DEFINITIONS

This section provides the definitions in common use throughout this document.

I.5.1 Time Systems

Three time systems are commonly used in this document.

I.5.1.1 Receiver Clock Time

The USO on board each spacecraft serves as the frequency and time reference for that GRACE satellite. The USO reference frequency is used to generate a near 38 MHz signal on-board, which, in turn, is used to sample both the GPS and KBR phase measurements. The transitions of the GPS zenith (navigation) antenna sampler define the receiver clock time. It is understood in the remainder of this document that the Receiver Clock Time refers to its specific realization on board each spacecraft.

The KBR and GPS measurements are time-tagged to within 50 picoseconds of the receiver clock time. The ACC and other data are time-tagged to within 100 microseconds of the receiver clock time. The receiver clock time, on board, is reckoned in seconds from the epoch of Jan 6, 1980. However, in Level-1A and Level-1B products, the time-tags in this time system will be given in seconds since epoch Jan 01, 2000, 1200 hrs.

I.5.1.2 GPS Time

The GPS Time is used as defined in the ICD-GPS-200 (Rockwell Int. Corp, Sep 1984). The process of orbit determination and clock correction using the GPS navigation & ground system data provides the connection between the receiver clock time and GPS time. GPS time is generally reckoned in weeks and seconds in week since Jan 6, 1980. However, in Level-1A and Level-1B products, time-tags in this time system will be given in seconds since epoch Jan 01, 2000, 1200 hrs.

I.5.1.3 Coordinated Universal Time (UTC)

The UTC is used as defined by the International Radio Consultative Committee (CCIR) Recommendation 460-4 (1986), and as maintained by the IERS.

I.5.1.4 Additional Note on OBDH Time

At certain places in this document, the “OBDH Time” terminology is used. This specialized notation is needed because of the timing interfaces on board the GRACE satellites between the GPS receiver and the On-Board Data Handler (OBDH), and its effect on the time-tagging of the Accelerometer & satellite housekeeping data. The understanding of this mapping is not relevant in general to the user, and this concept is included only because keeping a record of the TIM1A and TIM1B data products is useful for Level-1 processing.

I.5.2 Coordinate Systems

Several coordinate systems are used to define the various GRACE data products. The definitions are summarized in this section. The satellite body-fixed frames are shown in Figure I-2.

I.5.2.1 Science Reference Frame (SRF)

All Level-1B data products are specified in the Science Reference Frame (SRF). This reference frame is defined to have its origin at the center of mass of the satellite. The axes are directed by parallel to the measurement axes of the Accelerometer, such that

$$x_{SRF} \parallel z_{ACC}$$
$$y_{SRF} \parallel x_{ACC} \quad \text{(ACC least sensitive axis)}$$
$$z_{SRF} \parallel y_{ACC}$$

This reference frame is realized through the Star Camera head orientation quaternions, where the precise orientation of the star camera heads to the SRF is calculated as a result of the K-Band Calibration Maneuvers and pre-flight measurements. The origin is maintained by a Center of Mass Calibration & Trim maneuver.

I.5.2.2 K-Frame (KF)

With an origin coincident with the Science Reference Frame, the axes of the K-Frame are directed as follows

$$x_{KF} = \text{Line joining Satellite CM to K - Band antenna phase center}$$
$$y_{KF} \parallel z_{KF} \times x_{KF}$$
$$z_{KF} \parallel x_{KF} \times y_{SRF}$$

The K-Frame is realized, in conjunction with the SRF, as a result of the K-Band Calibration Maneuver. In the Science Modes, the spacecraft attitude control system attempts to point the x_{KF} axis of each satellite towards a target location of the other satellite.

I.5.2.3 Satellite Frame (SF)

With its origin at a target location for the center of mass of the proof mass of the Accelerometer, the Satellite Frame has its coordinate axes directed as follows:

x_{SF} = From the origin to a target location of the phase center on the boresight the K/Ka Band horn (Roll Axis);

y_{SF} = Forms a right-handed triad with x_{SF} and z_{SF} (Pitch Axis);

z_{SF} = Normal to x_{SF} and to the plane of the main equipment platform, and positive towards the satellite radiator (Yaw Axis)

The satellite frame was used as the basis for satellite assembly and payload unit alignment orientation on the ground.

During flight, the satellites have nadir-pointing Yaw axis orientation, with the Roll axes in the anti-flight and in-flight directions for the leading and trailing satellites, respectively.

I.5.2.4 Accelerometer Frame (AF)

With its origin at the center of mass of the proof mass of the ACC, the Accelerometer Frame is realized by the reference optical marks on the exterior surface. The accelerometer is accommodated such that:

$$x_{ACC} \parallel y_{SF} \quad \text{(ACC least sensitive axis)}$$
$$y_{ACC} \parallel z_{SF}$$
$$z_{ACC} \parallel x_{SF}$$

I.5.2.5 Star Camera Frame (SCF)

Each GRACE satellite carries two star camera assemblies. The origin of each Star Camera Frame is at the intersection of the optical axis (boresight) with the mounting plane for the star camera head. The Star Camera Head nomenclature is given in Section I.5.3.1. The axes are directed as follows, relative to the Satellite Frame (Figure I-2):

Star Camera ID=1

This star camera has its optical axis (z_{SCF_1}) in the $+y_{SF}/-z_{SF}$ quadrant, pointed nominally at 45° from the ($-z_{SF}$) direction. The x_{SCF_1} axis is parallel to the satellite (x_{SF}) axis.

Star Camera ID=2

This star camera has its optical axis (z_{SCF_2}) in the $-y_{SF}/-z_{SF}$ quadrant, pointed nominally at 45° from the ($-z_{SF}$) direction. The x_{SCF_2} axis is parallel to the satellite (x_{SF}) axis.

I.5.2.6 Inertial Frame

In this document, the Inertial Frame refers to the International Celestial Reference System (ICRS), with the reference frame realized by the J2000.0 Equatorial Coordinates.

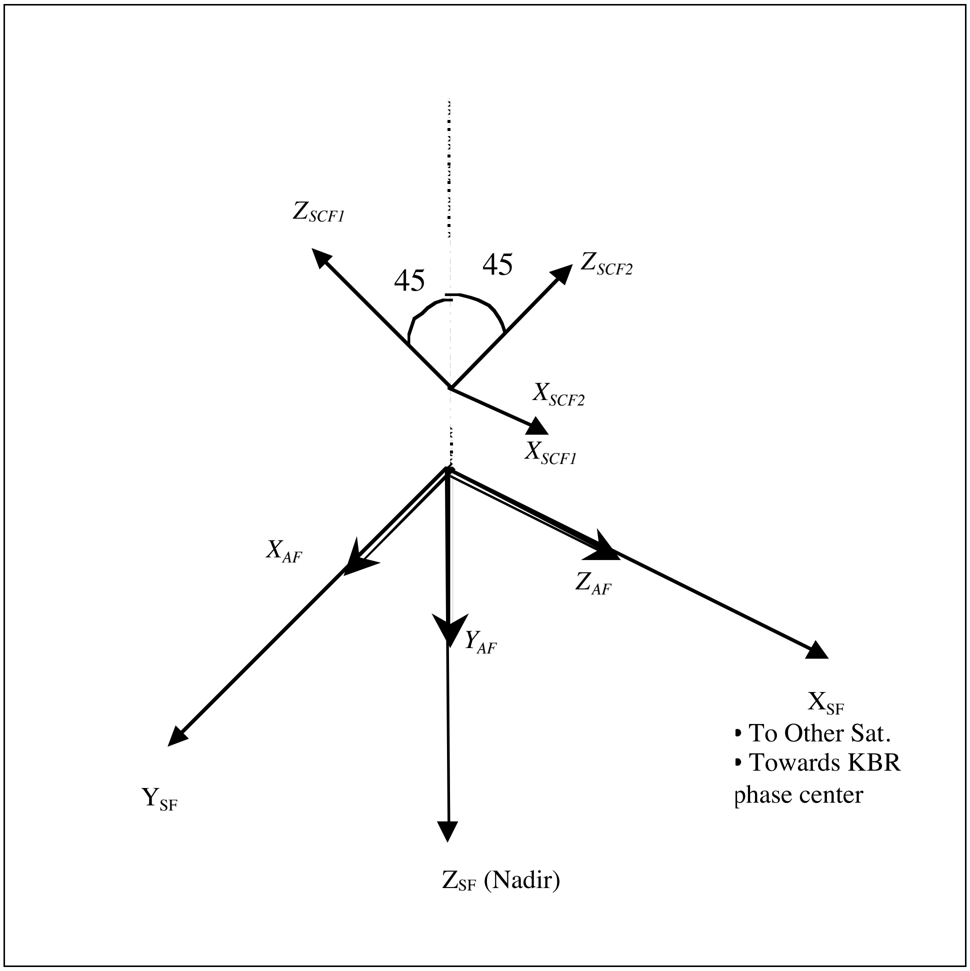

Figure I-2 Satellite body-fixed reference frames, with their origin at the Center of Mass of the proof-mass of the accelerometer.

I.5.2.7 Terrestrial Frame

In this document, the Terrestrial Frame refers to the Conventional Terrestrial Reference System, realized by the International Terrestrial Reference Frames as per the processing standards.

I.5.2.8 WGS84 Coordinates

The WGS84 are Earth-Centered, Earth-Fixed coordinates whose transformation with respect to the Terrestrial Frame is generally well known in the literature.

I.5.2.9 Important Usage Note

The diverse reference frames have been retained for compatibility with pre-flight alignment measurements, and other assembly activities at the payload unit or the satellite level. However, in general, all analysis pertaining to the satellite is carried out in the

Science Reference Frame within the SDS, and the Level-1B data are referenced relative to the SRF. By design, the Accelerometer is stably aligned relative to the Star Cameras, and this alignment is well calibrated with in-flight experiments. In conjunction with the K-Band calibration, the ranging and acceleration data is specified in a well-known Science Reference Frame. The coordinate system for each product is explicitly stated in addition, so that there is no ambiguity.

I.5.3 Satellite Description

In this section, certain attributes and useful properties of the twin GRACE satellites are described. In general, dimensions, locations and orientations in this section are provided in the Satellite Frame – unless otherwise specified. The distinction between the SF and the SRF should not be important for most of the conceived uses of the information in this section – the two may be regarded as the same here.

I.5.3.1 Satellite Nomenclature

The twin GRACE satellites are identical in every respect, except for the differences in the oscillator reference & the S-Band communication frequencies. The satellite & instruments designation is as follows:

Description	**Identifier**	
Science Nomenclature	GRACE-A	GRACE-B
Operations Nomenclature (GSOC)	GRACE-1	GRACE-2
Satellite System Nomenclature (Astrium)	FM-1	FM-2
USO Frequency	4.832000 MHz	4.832099 MHz
Downlink Carrier Frequency	2211.000 MHz	2260.800 MHz
Uplink Carrier Frequency	2051.000 MHz	2073.500 MHz
Relative position after launch	Leading	Trailing
Star Camera Heads	ID=1 or CHU9	ID=1 or CHU7
	ID=2 or CHU1	ID=2 or CHU3
Accelerometer	FM1	FM2

This information is superseded, in the event of a conflict, by the information in the Mission Plan Document (327-210) or the Satellite System Specification Document (GR-DSS-SP-001).

I.5.3.2 Thruster Accommodation

Each GRACE satellite has twelve 10mN GN2 thrusters for attitude control, and two 40 mN GN2 thrusters for orbit control. The thruster number, thruster ID, location (in **mm** relative to the Satellite Frame), nominal force (in **m**illi**N**ewtons), intended direction of control (**R**oll, **P**itch & **Y**aw relative to Satellite Frame), and firing directions (pointing **Ptg** in Satellite Frame) are as follows :

No.	ID	Location (mm)			Force (mN)			Ctrl	Ptg
		X	Y	Z	X	Y	Z		
1	A11	-1450	-719	0	0	10	0	Y(-)	-Y
2	A12	-1450	0	-444	0	0	10	P(+)	-Z
3	A13	-1450	719	0	0	-10	0	Y(+)	+Y
4	A14	-1450	0	275	0	0	-10	P(-)	+Z
5	A15	0	-970	300	0	10	0	R(-)	-Y
6	A16	0	-467	-300	0	10	0	R(+)	-Y
7	A21	1450	719	0	0	-10	0	Y(-)	+Y
8	A22	1450	0	275	0	0	-10	P(+)	+Z
9	A23	1450	-719	0	0	10	0	Y(+)	-Y
10	A24	1450	0	-444	0	0	10	P(-)	-Z
11	A25	0	467	-300	0	-10	0	R(-)	+Y
12	A26	0	970	300	0	-10	0	R(+)	+Y
13	O11	-1561	-275	0	39.4	6.9	0	dV	-X
14	O21	-1561	275	0	39.4	-6.9	0	dV	-X

This information is superseded, in the event of a conflict, by the information in the Satellite Specification Document (GR-DSS-SP-001).

I.5.3.3 GRACE Macro Model: Mass

The two GRACE satellites, in general, are identical to each other. All except certain key aspects of the physical properties of the GRACE satellite (the so-called Macro Model) are hence provided for only one satellite.

Satellite Mass at Launch

GRACE-A: 487.2 kg
GRACE-B: 487.2 kg

Mass values are updated during the mission, and provided in the MAS1A and MAS1B data products.

I.5.3.4 GRACE Macro Model: Exterior Dimensions

The following two figures show the exterior dimensions of the GRACE spacecrafts.

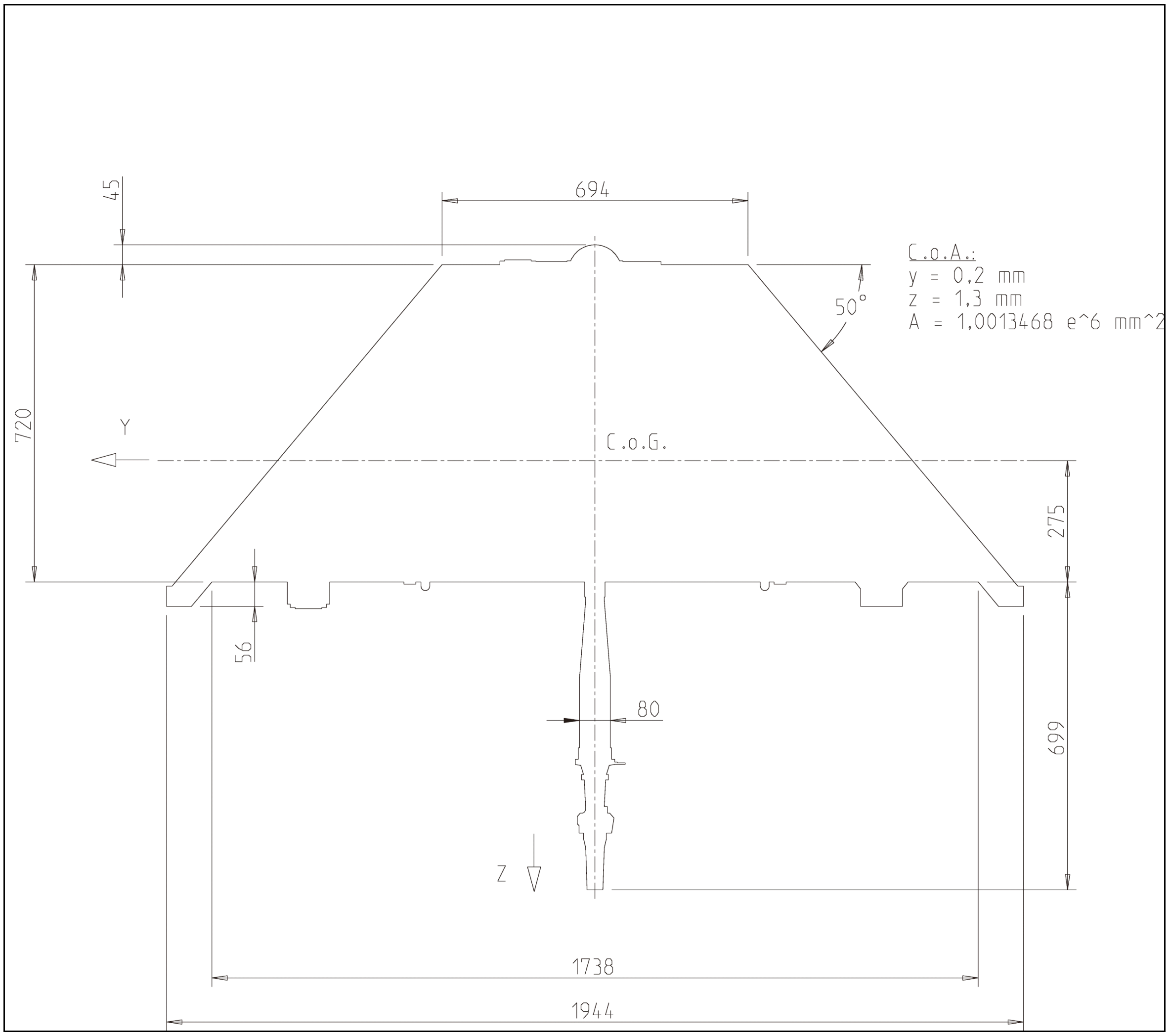

Figure 3 Projection in Y-Z plane in Satellite Frame (view from front). (All dimensions in mm)

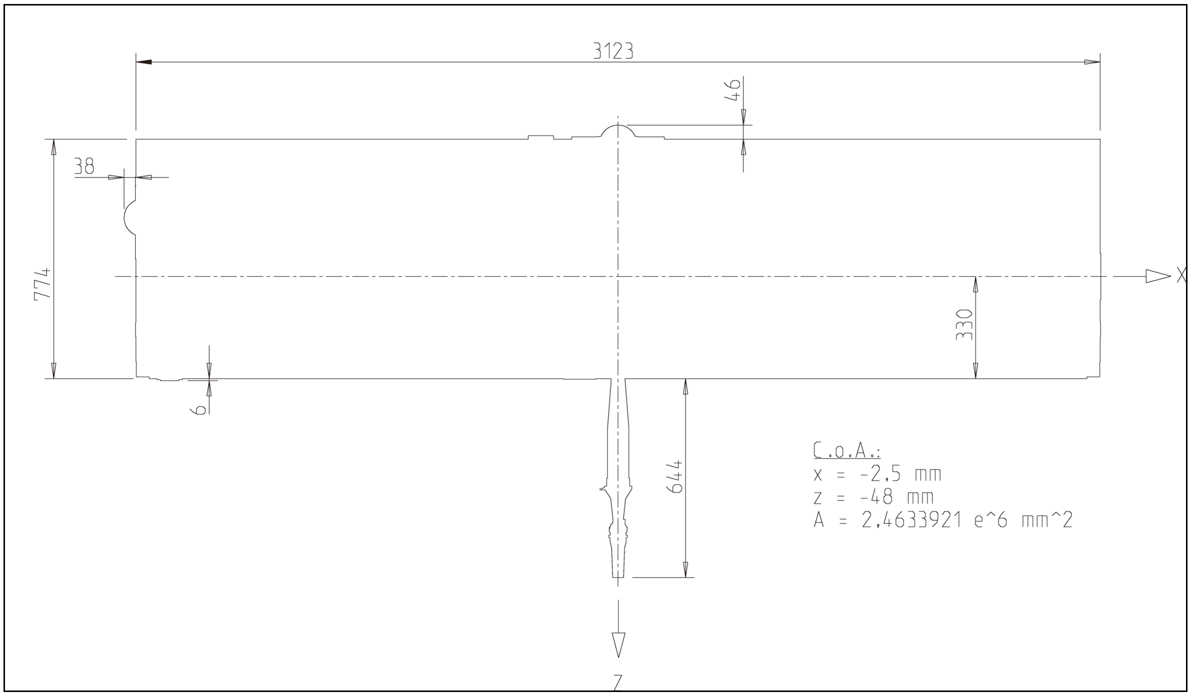

Figure 4 Projection in X-Z plane in Satellite Frame (view from Port) (All dimensions in mm)

I.5.3.5 GRACE Macro Model: Surface Properties

The surface properties are summarized in the following table. For each surface, the area, the components of its unit normal in the Satellite Frame, the material, as well as its emissivity and absorptivity/reflectivity coefficients are provided.

Panel	Area (m^2)	Unit Normal			Material	Emiss (IR)	Absorp (Vis)	Refl (Vis)		Refl (IR)	
		X	Y	Z				Geom	Diff	Geom	Diff
Front	0.9551567	+1.0	0.0	0.0	SiOx/Kapton	0.62	0.34	0.40	0.26	0.23	0.15
Rear	0.9551567	-1.0	0.0	0.0	SiOx/Kapton	0.62	0.34	0.40	0.26	0.23	0.15
Starboard (outer)	3.1554792	0.0	+0.766044	-0.642787	Si Glass Solar Array	0.81	0.65/0.72 (note 2)	0.05	0.30	0.03	0.16
Starboard (inner)	0.2282913	0.0	-0.766044	+0.642787	SiOx/Kapton	0.62	0.34	0.40	0.26	0.23	0.15
Port (outer)	3.1554792	0.0	-0.766044	-0.642787	Si Glass Solar Array	0.81	0.65/0.72 (note 2)	0.05	0.30	0.03	0.16
Port (inner)	0.2282913	0.0	+0.766044	+0.642787	SiOx/Kapton	0.62	0.34	0.40	0.26	0.23	0.15
Nadir	6.0711120	0.0	0.0	+1.0	Teflon (note 1)	0.75	0.12	0.68	0.20	0.19	0.06
Zenith	2.1673620	0.0	0.0	-1.0	Si Glass Solar Array	0.81	0.65/0.72	0.05	0.30	0.03	0.16
Boom	0.0461901 (note 4)	--	--	--	SiOx/Kapton (note 3)	0.62	0.34	0.40	0.26	0.23	0.15

(1) fluoro ethylene propylene
(2) 0.65 for operating solar array (i.e. power being drawn); 0.72 for non-operating array
(3) S-Band antenna on the boom is protected by a carbon radome (emiss = 0.85; absorp = 0.95), neglected here.
(4) Planar projection area of the cylindrical Boom, along any direction in the Satellite Frame (X-Y) plane.

I.5.3.6 GRACE Macro Model: Antenna Locations

The recommended values for the antenna locations, in the Science Reference Frame, are provided in the following Level-1B products, with "xx" denoting Version number.

Antenna	Product File Name	Remark
GPS Main	VGN1B_2004-05-31_A_xx.dat VGN1B_2004-05-31_B_xx.dat	Provides L1/L2 phase center offsets. Values used in Level-2 processing are separately given in the respective Proc Standards Documents.
GPS Backup	VGB1B_2004-05-31_A_xx.dat VGB1B_2004-05-31_B_xx.dat	Provides L1/L2 phase center offsets
GPS Occultation	VGO1B_2004-05-31_A_xx.dat VGO1B_2004-05-31_B_xx.dat	Provides L1/L2 phase center offsets
SLR Reflector	VSL1B_2004-05-31_A_xx.dat VSL1B_2004-05-31_B_xx.dat	The Z value already includes a 4 mm (additive) correction to the LRR optical phase center.
KBR Horn	VKB1B_2004-05-31_A_xx.dat VKB1B_2004-05-31_B_xx.dat	These values are derived from on-orbit KBR Calibration maneuvers.

I.5.3.7 Usage Note on Satellite Sensor Locations

Several products in this document provide the satellite or instrument housekeeping sensor measurements, such as temperatures and voltages. Detailed information about these sensors, including their locations or characteristics, are not provided in this document, but are available in various detailed unit or system level documentation.

In particular, should it become necessary to use such data for analysis, the complete usage guidelines for all such products will be provided in a self-contained manner.

I.5.4 Related Documents

For further details on the contents of the Level-1A and Level-1B products, as well as product interpretation and usage guidelines, the user may consult the *Level-1 User Handbook* and the *Level-1 Formats Document*.

Further details on the Level-2 products, and notes on interpretation are available in the *Level-2 User Handbook*. The models used for Level-2 data processing are in the *Level-2 Processing Standards Documents*.

II LEVEL-0 DATA PRODUCTS

II. 1 INTRODUCTION

This chapter contains the specification of the GRACE Level-0 data products. The GRACE RDC is responsible for the decommutation of the down-link data from each satellite into the respective science and housekeeping data streams. For each pass, from each satellite, the data streams are placed in two files, one containing the science data, and the other containing the housekeeping data. These files are placed in a rolling archive at the RDC. The GRACE SDS then retrieves these files, and thereon proceeds with the higher level processing activities.

The Level-0 data products are understood to be the two files for each satellite. The following two sections describe the contents of these data products. For completeness, however, the Appendix I contains a description of the content and formats of the individual Communication Packets (CP) and Application Packets (AP) which make up the two streams. This latter description is superseded, in the event of a conflict, by the description of the APs and CPs in the relevant on-board software and instrument specification documents.

Remark: Although the Appendix I identifies several "Products", it should be clearly noted that these products are neither created nor stored, nor made available as such. The Level-0 TM files lead directly to the Level-1A products, and the "product" nomenclature is used here as a mnemonic aid to the CPs or the APs contained within the TM files.

II. 2 SCIENCE DATA

The Science Data stream is defined in the On-Board Software Data Interfaces & Data Flow Document (GR-DJO-SW-0005). In summary, this file contains a stream of Time Stamp Packet (ID=255), each followed by the science Application Packets from the IPU (ID=250 or 251) and from the ICU (ID=252 or 253). Within each application packet are contained the Communication Packets from the source instrument. For reference, the names and contents of the relevant CPs are described in Appendix I.

II. 3 HOUSEKEEPING DATA

The Housekeeping Data stream is built up of data from various satellite instrument and software sub-systems by the OBDH. The stream of Time Stamp Packets is followed by various Application Packets, with ID in the range 160 to 255, excluding the science application packets. The contents of this file are also defined in GR-DJO-SW-0005.

III LEVEL-1A DATA PRODUCTS

III. 1 INTRODUCTION

The Level-0 data are acquired by the SDS from a rolling archive at the GRACE RDC. The data are then separated into respective instrument packets. The sensor calibration factors are applied to convert the data to engineering units, and data quality flags are added. Where necessary, the time tags are corrected to the respective satellite receiver clock time.

This reformatted data is denoted as the Level-1A product. The transition from Level-0 to Level-1A is non-destructive, and generally reversible except for the bad data packets. This chapter, besides the specification of the Level-1A data, also contains a description of the ancillary GRACE mission specific data inputs needed for Level-1 data processing.

III. 2 IPU DATA

This section contains a description of the Level-1A data originating in the IPU.

III.2.1 GPS Flight Receiver Data

Product Identifier	**GPS1A_(DATE)_A_RL** **GPS1A_(DATE)_B_RL**
Product Definition	• Time tag • Antenna indicator, PRN indicator & data flags. • One or more of CA, L1 & L2 data receiver channels, & for each, its SNR, carrier phase & pseudo-range measurement.
Representation	Time-tag: Seconds past 12:00:00 (noon) 01-Jan-2000
Units	Time: Seconds Phase: meters Pseudo-range: meters
System	Time Tag: Receiver Clock Time (within 70 picoseconds)
Resolution	*Nav Antenna Data:* Code & SNR @ 10 sec; Phase @ 1 sec. *Occ Antenna Data:* 50 Hz L1/L2 carrier phase & amplitude
Inputs	Level-0 GPS data from IPU
Data Volume	34 Mbytes/day/sat
Data Format	Level-1A Data Format: **GFD1X**
Latency	24 hours
Notes	30 hr data files (3 hr padding on daily file).

III.2.2 GPS On-Board Orbit Ephemerides

Product Identifier	**GNV1A_(DATE)_A_RL** **GNV1A_(DATE)_B_RL**
Product Definition	The on-board, IPU navigation solution, including • Solution Time • Chi-Squared & Covariance Precision Multiplier • Clock steering voltage • Receiver position & offset between GPS & Receiver time • Formal error in receiver position & time offset • Receiver velocity & time offset rate • Formal error in receiver velocity & time offset rate • PRN's used in solution, including their azimuth & elevation values
Representation	Time-tag : Seconds past 12:00:00 (noon) 01-Jan-2000
Units	Solution Time: Seconds Position & Velocity: m and m/second Time offset & offset rates: seconds & sec/sec Others: Dimensionless
System	Solution Time: Receiver Clock Time Position & Velocity: WGS-84
Resolution	60 seconds (all data)
Inputs	Level-0 GPS receiver data
Data Volume	< 3.5 Mbyte/day/sat
Data Format	Level-1A File Format: **GNV1A**
Latency	24 hours
Notes	Data from one day is stored in one file

III.2.3 Smoothed On-Board Clock Solution

Product Identifier	**CLK1A_(DATE)_A_RL** **CLK1A_(DATE)_B_RL**
Product Definition	Offset of the satellite receiver clock relative to GPS time, obtained by linear fit to raw on-board clock offset estimates.
Representation	Time-tag : Seconds past 12:00:00 (noon) 01-Jan-2000
Units	Solution Time: Seconds Time offset & offset rates: seconds & sec/sec
System	Time tag: Receiver Clock Time
Resolution	60 seconds
Inputs	GNV1A
Data Volume	5 Kbyte/day/sat
Data Format	Level-1A File Format: **CLK1B**
Latency	24 hours
Notes	30 hr data files (3 hr padding on daily file).

III.2.4 K-Band Ranging Data

Product Identifier	**KBR1A_(DATE)_A_RL** **KBR1A_(DATE)_B_RL**
Product Definition	• Time tag • K & Ka frequency integrated carrier phase • K & Ka band SNR
Representation	Time tag: Seconds past 12:00:00 (noon) 01-Jan-2000
Units	Time Tag: Seconds Phase: cycles SNR: volts/volt
System	Time Tag: Receiver Clock Time Phase: N/A
Resolution	0.1 seconds (all phase data)
Inputs	Level-0 IPU data
Data Volume	20 Mbytes/day/sat
Data Format	Level-1A File Format: **GFD1X**
Latency	1 day
Notes	All data from one Day are stored together.

III.2.5 Star Camera Data

Product Identifier	**SCA1A_(DATE)_A_RL** **SCA1A_(DATE)_B_RL**
Product Definition	• Time Tag & SCA head indicators • Quaternions specifying the inertial orientation of both Star Camera Heads. • Housekeeping data
Representation	Time-tag: Seconds past 12:00:00 (noon) 01-Jan-2000 Quaternions: I/J/K components & the cosμ/2 component
Units	Time Tag: Seconds Quaternions: N/A
System	Time Tag: Receiver Clock Time Quaternions: N/A
Resolution	Prime Star Camera Quaternions: 1 second Secondary Star Camera Quaternions: 1 seconds (variable)
Inputs	Level-0 SCA data from the IPU
Data Volume	8 Mbytes/day/sat
Data Format	Level-1A File Format: **SCA1A**
Latency	1 day
Notes	30 hr data files (3 hr padding on daily file).

III.2.6 IPU Housekeeping Data

Product Identifier	**IHK1A_(DATE)_A_RL** **IHK1A_(DATE)_B_RL**
Product Definition	• Time tag • IPU, SPU & SCA power supply voltages • IPU, MWA & KBR temperatures • KBR Switch settings
Representation	(TBD)
Units	Time: GPS Time Temp: °C Voltages: Volt
System	(TBD)
Resolution	(TBD)
Inputs	(TBD)
Data Volume	(TBD)
Data Format	Level-1A File Format: **IHK1X**
Latency	1 day
Notes	All data from one Day are stored together.

III. 3 ICU DATA

This section contains a description of the Level-1A data originating in the ICU.

III.3.1 Acceleration Science Data

Product Identifier	**ACC1A_(DATE)_A_RL** **ACC1A_(DATE)_B_RL**
Product Definition	• Time-tag: Time of data acquisition from the accelerometer. • Linear acceleration components of ACC proof mass relative to its electrode cage built up in 100 milliseconds following TTAG. • Angular acceleration components of ACC proof mass relative to its electrode cage built up in 100 milliseconds following TTAG.
Representation	N/A
Units	Timetag: Seconds Linear Accelerations: m/s^2 Angular Accelerations: rad/s^2
System	Timetag: Receiver Clock Time (within 100 micro-seconds) Linear & Angular Accelerations: Accelerometer Frame
Resolution	Time-Tag: 0.1 seconds Linear Accelerations: 0.1 seconds Angular Accelerations: 1.0 seconds
Inputs	Level-0 Accelerometer Data Spacecraft Time Stamp Packets Sensor calibration factors
Data Volume	30 Mbytes/day/sat
Data Format	Level-1A File Format: **ACC1A**
Latency	1 day
Notes	All data from one Day are stored together.

III.3.2 Accelerometer Housekeeping Data

Product Identifier	**AHK1A_(DATE)_A_RL** **AHK1A_(DATE)_B_RL**
Product Definition	• Time-tag: Time of data acquisition from the accelerometer. • Proof-mass bias voltage, Capacitive Sensor output & working order • ICU & SU temperatures, reference voltages & primary and secondary power supply voltage.
Representation	N/A
Units	Timetag: Seconds Temperatures: °C Voltages : Volts
System	Timetag: Receiver Clock Time (within 100 micro-seconds)
Resolution	Bias Voltage & Capacitive Sensor output : 10 seconds Others : 60 seconds
Inputs	Level-0 Accelerometer Data Spacecraft Time Stamp Packets Sensor calibration factors
Data Volume	< 1 Mbytes/day/sat
Data Format	Level-1A File Format: **ACC1A**
Latency	1 day
Notes	All data from one Day are stored together.

III. 4 SPACECRAFT HOUSEKEEPING DATA

This section defines the products extracted from the spacecraft housekeeping data stream, which are useful for generation of products at subsequent levels. This also includes additional intermediate products, derived from some mix of house-keeping and ground analyses results.

III.4.1 OBDH to GPS Time Mapping

Product Identifier	**TIM1A_(DATE)_A_RL** **TIM1A_(DATE)_B_RL**
Product Definition	Mapping between the time kept by the & GPS time determined by the IPU
Representation	Time-tag : Seconds past 12:00:00 (noon) 01-Jan-2000
Units	Solution Time: Seconds Time offset & offset rates: seconds & sec/sec
System	Time tag: Receiver Clock Time
Resolution	60 seconds
Inputs	GNV1A
Data Volume	< 1 Mbyte/day/sat
Data Format	Level-1A File Format: **TIM1X**
Latency	24 hours
Notes	Data from one Day is stored in one file

III.4.2 Magnetometer & Magnetorquer Data

Product Identifier	**MAG1A_(DATE)_A_RL** **MAG1A_(DATE)_B_RL**
Product Definition	• X/Y/Z measured components of Earth magnetic fields • Magnetorquer currents
Representation	N/A
Units	Time tag: seconds MAG: nano-Tesla MTQ currents: Amps
System	Time Tag: On-board receiver time MAG: In Satellite Frame
Resolution	60 second
Inputs	Spacecraft housekeeping data
Data Volume	< 1 Mbytes/day/sat
Data Format	Level-1B file format: **MAG1X**
Latency	24 hours
Notes	

III.4.3 Thruster Activation Data

Product Identifier	**THR1A_(DATE)_A_RL** **THR1A_(DATE)_B_RL**
Product Definition	• Activation Time Tag • Cumulative work cycles for all thrusters • On-Time for present activation for all thrusters • Cumulative on-time for all thrusters
Representation	32-bit fixed point, so that the cumulative numbers wrap around at 4294967295 (= 2^{32}-1)
Units	Time tag: seconds On-Time: milli-seconds
System	Time: On-board receiver time
Resolution	At each thruster activation epoch
Inputs	Level-0 spacecraft housekeeping data
Data Volume	< 1Mbytes/day/sat average
Data Format	Level-1B file format: **THR1X**
Latency	24 hours
Notes	See section I.5.3.2 for accomodation & firing direction of thrusters

III.4.4 Tank Sensor Information

Product Identifier	**TNK1A_(DATE)_A_RL** **TNK1A_(DATE)_B_RL**
Product Definition	• Time Tag • Pressures : Tank internal & at pressure regulator • Temperatures: Skin & tank adaptor temperature
Representation	N/A
Units	Time tag: seconds Pressure: Bars Temperature: °C
System	Time: On-board receiver time
Resolution	60 seconds
Inputs	Level-0 spacecraft housekeeping data
Data Volume	< 1 Mbytes/day/sat average
Data Format	Level-1B file format: **TNK1X**
Latency	24 hours
Notes	See Satellite Specification Document for locations of the temperature & pressure sensors.

III.4.5 Satellite Mass Information

Product Identifier	**MAS1A_(DATE)_A_RL** **MAS1A_(DATE)_B_RL**
Product Definition	• Time Tag • Spacecraft mass & error estimate based on thruster usage • Spacecraft mass & error estimate based on tank sensors
Representation	N/A
Units	Time tag: seconds Mass : kg
System	Time: On-board receiver time
Resolution	TBD
Inputs	TNK1A & THK1A
Data Volume	< 1Mbyte/day/sat (average)
Data Format	Level-1B file format: **MAS1X**
Latency	24 hours
Notes	

IV LEVEL-1B DATA PRODUCTS

IV. 1 INTRODUCTION

The Level-1B data products are derived from the (possibly irreversible) processing of the data products from previous levels. The data will have been edited and decimated from the high rate samples of the instrument to the low rate samples useable for further science analysis. In addition to the spacecraft data, this chapter also contains a description of the GRACE specific data products generated by the GRACE SDS for further processing to higher levels.

IV. 2 IPU DATA

This section contains a description of the Level-1B data largely originating in the IPU.

IV.2.1 GPS Flight Receiver Data

Product Identifier	**GPS1B_(DATE)_A_RL** **GPS1B_(DATE)_B_RL**
Product Definition	• Time tag • Antenna indicator, PRN indicator & data flags. • One or more of CA, L1 & L2 data receiver channels, & for each, its SNR, carrier phase & pseudo-range measurement.
Representation	Time-tag: Seconds past 12:00:00 (noon) 01-Jan-2000
Units	Time: Seconds Phase: meters Pseudo-range: meters
System	Time Tag: GPS Time
Resolution	*Nav Antenna Data:* 10 seconds
Inputs	Level-1A GPS data from IPU & ancillary data
Data Volume	4 Mbytes/day/sat
Data Format	Level-1B Data Format: **GFD1X**
Latency	1 day
Notes	Data from one Day is stored in one file.

IV.2.2 Precise GRACE Satellite Orbit Ephemerides

Product Identifier	**GNV1B_(DATE)_A_RL** **GNV1B_(DATE)_B_RL**
Product Definition	The precise orbit information, including • Solution Time • Receiver position & velocity • Formal error in receiver position & velocity
Representation	Time-tag : Seconds past 12:00:00 (noon) 01-Jan-2000
Units	Solution Time: Seconds Position & Velocity: m and m/second
System	Solution Time: GPS Time Position & Velocity: Inertial or Terrestrial Frame (as flagged)
Resolution	30 seconds
Inputs	Level-1A GPS receiver & ancillary data
Data Volume	< 1 Mbyte/day/sat
Data Format	Level-1B File Format: **GNV1B**
Latency	≈ 12 days
Notes	Data from one Day is stored in one file

IV.2.3 Precise Clock Solution

Product Identifier	**CLK1B_(DATE)_A_RL** **CLK1B_(DATE)_B_RL**
Product Definition	Offset of the satellite receiver clock relative to GPS time.
Representation	Time-tag : Seconds past 12:00:00 (noon) 01-Jan-2000
Units	Solution Time: Seconds Time offset: seconds
System	Time tag: Receiver Clock Time
Resolution	30 seconds
Inputs	Level-1A GPS receiver & ancillary data
Data Volume	< 1 Mbyte/day/sat
Data Format	Level-1B File Format: **CLK1B**
Latency	≈ 12 days
Notes	Data from one Day is stored in one file

IV.2.4 USO Frequency Estimate

Product Identifier	**USO1B_(DATE)_A_RL** **USO1B_(DATE)_B_RL**
Product Definition	• Time tag & USO ID • Frequency of the USO.
Representation	Time-tag : Seconds past 12:00:00 (noon) 01-Jan-2000
Units	Solution Time: Seconds Frequency: Hertz
System	Time tag: GPS Time
Resolution	Daily
Inputs	CLK1B
Data Volume	< 1 Mbyte/day/sat
Data Format	Level-1B File Format: **OSCFQ**
Latency	≈ 12 days
Notes	Data from one Day is stored in one file

IV.2.5 Dual-One-Way Ranging Data

Product Identifier	**KBR1B_(DATE)_X_RL**
Product Definition	• Time tag • Biased Range, Range-Rate & Range-Accelerations between the C.G. of the two GRACE satellites. • Ionospheric corrections • Light-time corrections • KBR antenna phase center range correction
Representation	Time tag: Seconds past 12:00:00 (noon) 01-Jan-2000
Units	Time Tag: Seconds Range & Derivatives : m, m/s, m/s^2 Corrections: m
System	Time Tag: GPS Time
Resolution	5 seconds
Inputs	Level-1A IPU and other ancillary data
Data Volume	2 Mbytes/day
Data Format	Level-1A File Format: **KBR1B**
Latency	≈ 12 days
Notes	All data from one Day are stored together.

IV.2.6 Star Camera Data

Product Identifier	**SCA1B_(DATE)_A_RL** **SCA1B_(DATE)_B_RL**
Product Definition	• Time Tag & SCA head indicators • Quaternions specifying the inertial orientation of the Science Reference Frame. • Housekeeping data
Representation	Time-tag: Seconds past 12:00:00 (noon) 01-Jan-2000 Quaternions: I/J/K components & the cosμ/2 component
Units	Time Tag: Seconds Quaternions: N/A
System	Time Tag: GPS Time Quaternions: N/A
Resolution	Quaternions: 5 second
Inputs	SCA1A, CLK1B & QSA1B
Data Volume	< 1 Mbytes/day/sat
Data Format	Level-1A File Format: **SCA1B**
Latency	≈ 12 days
Notes	All data from one Day are stored together.

IV.2.7 IPU Housekeeping Data

Product Identifier	**IHK1B_(DATE)_A_RL** **IHK1B_(DATE)_B_RL**
Product Definition	• Time tag • IPU, SPU & SCA power supply voltages • IPU, MWA & KBR temperatures • KBR Switch settings
Representation	(TBD)
Units	Time: Sec past 12:00 (noon), Jan 01, 2000 Temp: °C Voltages: Volts
System	(TBD)
Resolution	(TBD)
Inputs	(TBD)
Data Volume	(TBD)
Data Format	Level-1A File Format: **IHK1X**
Latency	1 day
Notes	All data from one Day are stored together.

IV. 3 ICU DATA

This section contains a description of the Level-1A data originating in the ICU.

IV.3.1 Acceleration Data

Product Identifier	**ACC1B_(DATE)_A_RL** **ACC1B_(DATE)_B_RL**
Product Definition	• Time-tag. • Linear & Angular acceleration components of ACC proof mass relative to its electrode.
Representation	N/A
Units	Timetag: Seconds Linear Accelerations: m/s^2 Angular Accelerations: rad/s^2
System	Timetag: GPS Time Linear & Angular Accelerations: Science Reference Frame
Resolution	1 seconds
Inputs	Level-1A Accelerometer & ancillary data
Data Volume	7 Mbytes/day/sat
Data Format	Level-1B File Format: **ACC1B**
Latency	≈ 12 days
Notes	All data from one Day are stored together.

IV.3.2 Accelerometer Housekeeping Data

Product Identifier	**AHK1B_(DATE)_A_RL** **AHK1B_(DATE)_B_RL**
Product Definition	• Time-tag: Time of data acquisition from the accelerometer. • Proof-mass bias voltage, Capacitive Sensor output & working order • ICU & SU temperatures, reference voltages & primary and secondary power supply voltage.
Representation	N/A
Units	Timetag: Seconds Temperatures: °C Voltages : Volts
System	Timetag: GPS Time
Resolution	Bias Voltage & Capacitive Sensor output : 10 seconds Others : 60 seconds
Inputs	Level-1A Accelerometer & Ancillary Data
Data Volume	< 1 Mbytes/day/sat
Data Format	Level-1B File Format: **ACC1A**
Latency	1 day
Notes	All data from one Day are stored together.

IV. 4 SPACECRAFT HOUSEKEEPING DATA

This section defines the products extracted from the spacecraft housekeeping data stream, which are useful for generation of products at subsequent levels.

IV.4.1 Magnetometer & Magnetorquer Data

Product Identifier	**MAG1B_(DATE)_A_RL** **MAG1B_(DATE)_B_RL**
Product Definition	• X/Y/Z measured components of Earth magnetic fields • Magnetorquer currents
Representation	N/A
Units	Time tag: seconds MAG: nano-Tesla MTQ currents: Amps
System	Time Tag: GPS Time MAG: In Satellite Frame
Resolution	60 second
Inputs	MAG1A, CLK1B
Data Volume	< 1 Mbyte/day/sat
Data Format	Level-1B file format: **MAG1X**
Latency	≈ 12 days
Notes	

IV.4.2 Thruster Activation Data

Product Identifier	**THR1B_(DATE)_A_RL** **THR1B_(DATE)_B_RL**
Product Definition	• Activation Time Tag • Cumulative work cycles for all thrusters • On-Time for present activation for all thrusters • Cumulative on-time for all thrusters
Representation	32-bit fixed point, so that the cumulative numbers wrap around at 4294967295 (= 2^{32}-1)
Units	Time tag: seconds On-Time: milli-seconds
System	Time: GPS Time
Resolution	At each thruster activation epoch
Inputs	THR1A, CLK1B
Data Volume	< 1 Mbyte/day/sat (average)
Data Format	Level-1B file format: **THR1X**
Latency	≈ 12 days
Notes	See (I.5.3.2) for accomodation & firing direction of thrusters

IV.4.3 Tank Sensor Information

Product Identifier	**TNK1B_(DATE)_A_RL** **TNK1B_(DATE)_B_RL**
Product Definition	• Time Tag • Pressures : Tank internal & at pressure regulator • Temperatures: Skin & tank adaptor temperature
Representation	N/A
Units	Time tag: seconds
System	Time: GPS Time
Resolution	TBD
Inputs	TNK1A, CLK1B
Data Volume	< 1 Mbyte/day/sat (average)
Data Format	Level-1B file format: **TNK1X**
Latency	≈ 12 days
Notes	See Satellite Specification Document for locations of the temperature & pressure sensors.

IV.4.4 Satellite Mass Information

Product Identifier	**MAS1B_(DATE)_A_RL** **MAS1B_(DATE)_B_RL**
Product Definition	• Time Tag • Spacecraft mass & error estimate based on thruster usage • Spacecraft mass & error estimate based on tank sensors
Representation	N/A
Units	Time tag: seconds Mass : kg
System	Time: GPS Time
Resolution	TBD
Inputs	MAS1A, CLK1B
Data Volume	< 1 Mbyte/day/sat (average)
Data Format	Level-1B file format: **MAS1X**
Latency	≈ 12 days
Notes	

IV.4.5 OBDH to GPS Time Mapping

Product Identifier	**TIM1B_(DATE)_A_RL** **TIM1B_(DATE)_B_RL**
Product Definition	Mapping between the time kept by the & GPS time determined by the IPU
Representation	Time-tag : Seconds past 12:00:00 (noon) 01-Jan-2000
Units	Solution Time: Seconds Time offset & offset rates: seconds & sec/sec
System	Time tag: Receiver Clock Time
Resolution	60 seconds
Inputs	GNV1A
Data Volume	< 1 Mbyte/day/sat
Data Format	Level-1A File Format: **TIM1X**
Latency	24 hours
Notes	Data from one Day is stored in one file

IV. 5 Ancillary GRACE Data

This section contains a description of ancillary data related to the GRACE satellites. These data may be gathered during flight or in pre-flight testing, or from independent analyses carried out specifically for GRACE, and are anticipated to be useful in the analysis of the GRACE flight data at all levels.

IV.5.1 Star Camera Heads Orientation wrt SRF

Product Identifier	**QSA1B_(DATE)_A_RL** **QSA1B_(DATE)_B_RL**
Product Definition	Quaternion of the orientation of each Star Camera head relative to the Science Reference Frame..
Representation	Quaternions: Vector-I/J/K components & the Scale component
Units	N/A
System	N/A
Resolution	Updated as necessary
Inputs	Results from pre-flight ground tests and analyses
Data Volume	N/A
Data Format	Level-1B format : **SCA1B**
Latency	N/A
Notes	One file will contain this information for mission duration

IV.5.2 Satellite Frame Orientation wrt SRF

Product Identifier	**QSB1B_(DATE)_A_RL** **QSB1B_(DATE)_B_RL**
Product Definition	Quaternion of the orientation of the Satellite Frame relative to the Science Reference Frame.
Representation	Quaternions: Vector-I/J/K components & the Scale component
Units	N/A
System	N/A
Resolution	Updated as necessary
Inputs	Results from pre-flight ground tests and analyses
Data Volume	N/A
Data Format	Level-1B format : **SCA1B**
Latency	N/A
Notes	One file will contain this information for mission duration

IV.5.3 Star Camera Heads Orientation wrt K-Frame

Product Identifier	**QKS1B_(DATE)_A_RL** **QKS1B_(DATE)_B_RL**
Product Definition	Quaternion of the orientations of the Star Camera heads relative to the K-Frame.
Representation	N/A
Units	N/A
System	N/A
Resolution	Valid until next in-flight calibation.
Inputs	Results from in-flight calibration measurements.
Data Volume	N/A
Data Format	Level-1 Data Format: **SCA1B**
Latency	N/A
Notes	

IV.5.4 Center of Mass Offset Estimate

Product Identifier	**VCM1B_(DATE)_A_RL** **VCM1B_(DATE)_B_RL**
Product Definition	Estimate of the vector offset of the satellite center of mass relative to the proof-mass center location.
Representation	N/A
Units	m
System	Science Reference Frame
Resolution	Valid until the next in-flight CG Calibration Maneuver
Inputs	Results from in-flight calibrations and analyses
Data Volume	N/A
Data Format	Level-1B format : **XXXVO**
Latency	N/A
Notes	

IV.5.5 GPS Navigation Antenna Offset

Product Identifier	**VGN1B_(DATE)_A_RL** **VGN1B_(DATE)_B_RL**
Product Definition	Components of the vector between the satellite center of mass and the GPS (zenith) navigation antenna phase center.
Representation	N/A
Units	meters
System	Science Reference Frame
Resolution	Valid for mission lifetime
Inputs	Results from pre-flight measurements.
Data Volume	N/A
Data Format	Level-1B Format: **XXXVO**
Latency	N/A
Notes	

IV.5.6 K-Band Antenna Offset Estimate

Product Identifier	**VKB1B_(DATE)_A_RL** **VKB1B_(DATE)_B_RL**
Product Definition	Components of the vector between the satellite center of mass and the phase center of K-Band antenna.
Representation	N/A
Units	meters
System	Science Reference Frame
Resolution	Valid until the next KBR Calibration maneuver
Inputs	Results from in-flight calibrations & analyses.
Data Volume	N/A
Data Format	Level-1B Format: **XXXVO**
Latency	N/A
Notes	

IV.5.7 GPS Occultation Antenna Offset

Product Identifier	**VGO1B_(DATE)_A_RL** **VGO1B_(DATE)_B_RL**
Product Definition	Components of the vector from the satellite center of mass to the GPS (aft) occultation antenna phase center.
Representation	N/A
Units	meters
System	Science Reference Frame
Resolution	Valid for mission duration.
Inputs	Results from pre-flight measurements.
Data Volume	N/A
Data Format	Level-1B Format: **XXXVO**
Latency	N/A
Notes	

IV.5.8 GPS Back-Up Antenna Offset

Product Identifier	**VGB1B_(DATE)_A_RL** **VGB1B_(DATE)_B_RL**
Product Definition	Components of the vector from the satellite center of mass to the GPS (aft) back-up antenna phase center.
Representation	N/A
Units	meters
System	Science Reference Frame
Resolution	Valid for mission duration.
Inputs	Results from pre-flight measurements.
Data Volume	N/A
Data Format	Level-1B Format: **XXXVO**
Latency	N/A
Notes	

IV.5.9 SLR Corner Cube Offset

Product Identifier	**VSL1B_(DATE)_A_RL** **VSL1B_(DATE)_B_RL**
Product Definition	Components of the vector from the satellite center of mass to the center of the SLR corner cube array.
Representation	N/A
Units	meters
System	Science Reference Frame
Resolution	Valid for mission duration.
Inputs	Results from pre-flight measurements.
Data Volume	N/A
Data Format	Level-1B Format: **XXXVO**
Latency	N/A
Notes	

IV.5.10 Input Time-Variable Atmospheric Gravity Model

Product Identifier	**AOD1B_(DATE)_X_RL**
Product Definition	Time series of fully-normalized spherical harmonic coefficients of the geopotential contributions from combined ECMWF Atmospheric and JPL Barotropic ocean model – including the individual atmospheric and oceanic components as well as the sum total.
Representation	N/A
Units	Time tag : Days Coefficients : Dimensionless
System	N/A
Resolution	Time: 6 hours Space: Max degree/order 100
Inputs	Level-1B ancillary data
Data Volume	0.9 Mb/day
Data Format	Level-1 Format: **AOD1B**
Latency	≈ 12 days
Notes	For the processing algorithm & input data description, please see *AOD1B Product Description Document*.

IV.5.11 Ocean Bottom Pressure Load Model

Product Identifier	**OCN1B_(DATE)_X_RL**
Product Definition	Time series of grids of ocean bottom pressures from JPL Barotropic ocean model.
Representation	N/A
Units	Time tag : Days Bottom Pressure : mBar
System	Earth Fixed Frame
Resolution	Time: 6 hours Space: 1.125° Lat/Lon equi-angular grid
Inputs	Level-1B ancillary data
Data Volume	2.5 Mb/day
Data Format	Level-1 Format: **OCN1B**
Latency	≈ 12 days
Notes	For the processing algorithm & input data description, please see *AOD1B Product Document*.

V LEVEL-2 DATA PRODUCTS

V. 1 INTRODUCTION

The Level-2 products are derived by processing the Level-1B and other ancillary data. Instrument measurements over several days are consolidated into a sequence of gravity field estimates, representing the time-variable and average Earth gravity field models.

The details behind the Level-2 product nomenclature are given in the *Level-2 Product User Handbook* – where a more detailed description of the content is provided. Since the Level-2 product nomenclature deviates from the conventions for Level-1 products, they are described differently from the Level-1 products. The following section is extracted from the *Level-2 Product User Handbook*.

V. 2 PRODUCT INDENTIFIER

A GRACE Level-2 gravity field product is a set of spherical harmonic coefficients of the exterior geopotential. A product name is specified as

PID-2_YYYYDOY-YYYYDOY_dddd_sssss_mmmm_rrrr

Where

PID is 3-character product identification mnemonic
-2 denotes a GRACE Level-2 product
YYYYDOY-YYYYDOY specifies the date range (in year and day-of-year format) of the data used in creating this product
dddd is the (leading-zero-padded) number of calendar days from which data was used in creating the product.
sssss is an institution specific string
mmmm is a 4-character free string (e.g. used for distinguishing constrained from unconstrained solutions)
rrrr is a 4-digit (leading-zero-padded) release number (0000, 0001, …)

The Product Identifier mnemonic (PID) is made up of one of the following values for each of its 3 characters:

1st Character

= G: Geopotential coefficients

2nd Character

= S: Estimate made from only GRACE data

= C: Combination estimate from GRACE and terrestrial gravity information
= E: Any background model specified as a time-series
= A: Average of any background model over a time period

3rd Character

= M: Estimate of the Static field.
(The data files for this product also contain records with the epochs & rates used to model secular changes in the background gravity model)
= U: Geopotential estimate relative to the background gravity model
= T: Total background gravity model except for background static model
= A: non-tidal atmosphere (see *AOD1B Description Doc*)
= B: non-tidal Oceans (see *AOD1B Description Doc*)
= C: combination of non-tidal atmosphere and ocean -
for details of combination see *AOD1B Description Doc*
= D: bottom pressure product – combination of surface pressure and ocean over the oceans, and zero over land. For details, please see *AOD1B Description Doc*

Not all possible combinations of characters make sense, or are provided as products. As of this release, the list of defined products, and the associated format names, is summarized in Table 1.

PID	Format	Remarks
GSM	GRCOF2	
GCM	GRCOF2	
GAA	GRCOF2	
GAB	GRCOF2	
GAC	GRCOF2	
GAD	GRCOF2	

Table 1 Product Identifiers and associated formats

Special Note-1: Change of Product Name

As of this release of the *GRACE L-2 Product User Manual,* the Level-2 product naming convention has changed. The string *_dddd_* has been moved behind the *_YYYYDOY-YYYYDOY_* string in the product name.

Special Note-2: Usage History of Level-2 Product Name

UTCSR has produced RL01 Level-2 products in the old naming convention, and adopted the new naming convention starting from RL02 products.

GFZ has produced RL01 and RL02 Level-2 products in the old naming convention, and changed to the new names with RL03 products.

JPL has produced RL01 products in the old naming convention, and adopted the new convention with its RL02 products.

Special Note-3: Usage History of Release Numbers

UTCSR has distributed Release-01 (ongoing until further notice) and Release-02 (defunct) Level-2 data products. The UTCSR Release-03 does not exist, and the next release is labeled Release-04, in order to synchronize with other SDS centers.

GFZ has distributed Release-01 (defunct), Release-02 (defunct) and Release-03 (ongoing) data products. The next release is labeled Release-04.

JPL has distributed Release-01 (defunct) and Release-02 (defunct). The next release is labeled Release-04.

V. 3 PRODUCT ATTRIBUTES

The geopotential is represented by the fully-normalized coefficients of a spherical harmonic expansion, to a specified maximum degree and order.

The time-variability of the geopotential is nominally represented by a sequence of approximately 30-day estimates of the spherical harmonic coefficients.

The maximum degree and order of the monthly estimates will be at most 100, and that for an estimate of the long-term mean will be at least 160.

The monthly estimates will be produced with a 60-day latency from, and estimates of long-term mean will be produced occasionally, as the results warrant.

Each data product will consist of one gravity field solution – which will have been made using GRACE data within a specified span.

VI APPENDIX

VI. 1 BACKGROUND

In the GRACE mission, the Instruments Processing Unit (IPU) delivers all data from the K-Band Ranging Assembly, the GPS receiver, and the Star Camera Assemblies at its science output port. The Accelerometer data are delivered by its Interface Control Unit (ICU). Additional data from the bus sub-systems or softwares are collected by the On-Board Data Handler (OBDH) and delivered as House-keeping Data. All the Communication Packets (CPs) are collected at the OBDH and repackaged and delivered for downlink. Most CP measurement contents are binary encoded (non-engineering units), and are described as assembled by the respective science instrument assemblies on board the GRACE satellites.

For completeness, the contents of the relevant CPs are described in this section, with appropriate references to the originating documents for the complete definition of their contents.

It must be emphasized that this Appendix is included in this document only for ease of future reference, and to complete the link between this document and the individual unit specifications. None of these products are either stored as such, nor are they intended for distribution.

In the event of a conflict, the descriptions in the referenced unit or satellite level documents supersede this document.

VI. 2 Accelerometer Data

The accelerometers provide measurements of the non-gravitational forces acting on each satellite by measuring the electrostatic forces required to keep a proof-mass centered within its electrode cage. These measurements serve to separate the non-gravitational from the gravitational effects in the intersatellite range changes.

Packet Identifier	**ICU_M or ICU_R**
Product Definition	• *0.1 second data:* Time of data acquisition & Linear acceleration components of ACC proof-mass relative to its electrode cage. • *1 second data:* Angular acceleration components of ACC proof mass relative to its electrode cage. • *10 second data:* Proof-mass bias voltage, capacitive sensors output & sensor working order • *60 second data:* SU & ICU temperatures, reference voltages & primary and secondary power supply voltages.
Representation	Time Tag: Relative to the last 1 Hz synchronization pulse received from the IPU (< 10 Seconds) Linear Accelerations: Built up in 100 milliseconds preceding TTAG Angular Accelerations: Builit up in 1 second preceding the TTAG.
Units	Non-Dimensional (Binary-encoded, non-engineering units)
System	Time Tag: Receiver Clock Time (within 100 micro-seconds) Linear & Angular Accelerations: Accelerometer Frame
Resolution	Time-Tag: 0.1 seconds Linear Accelerations: 0.1 seconds Angular Accelerations: 1.0 seconds Proof-mass Bias Voltage : 10 seconds Others : Last collected sample
Inputs	N/A
Data Volume	11.7 Mbytes/day (average)
Data Format	One-Second data block per packet, with contents augmented at intervals as specified above. *24 bit fixed-point binary:* TTAG, Linear & Angular Accelerations & Proof-mass bias voltage *12 bit fixed-point binary:* All others
Latency	As per data dump schedule
Notes	Ref: Section 3.4 & 5.4 in ACC Spec (327-520) Each one second packet may contain 10 or 11 samples of linear accelerations.

VI. 3 IPU DATA

The IPU is the nerve center for the spacecraft. It provides digital signal processing functions for the GPS data, for the K-Band ranging data and for the Star Camera assemblies. In addition, the IPU also provides the orbit and time references for the other spacecraft systems and functions. The following sections describe all the CPs expected to be available from the IPU during nominal science operations.

VI.3.1 KBR, GPS-OD & GPS-OCC Phase Data

Product Identifier	**QuadraticFitObservables**
Product Definition	• Time of quadratic fit point • PRN or KBR indicator, ASIC antenna number, data flags & sample interval of quadratic fit data. • One or more of CA, P1 & P2 data receiver channel, & its SNR, carrier phase & pseudo-range measurement. • *Alternatively*, the KBR data receiver channel & its SNR, carrier phase measurement. • Carrier phase doppler and doppler rate • One or more of CA, P1 & P2 channel carrier amplitude and/or carrier phase residuals inside the quadratic fit interval, at specified variable rates (for either OD data or OCC data) • *Alternatively*, the KBR amplitude and/or phase residuals inside the quadratic fit interval.
Representation	CA Data: Carrier Phase: in L1 cycles pseudo-range: in CA chips P1 Data: Carrier Phase: Difference between P1 & CA channel measurement, in L1 cycles pseudo-range: Difference between P1 & CA ranges in CA chips P2 Data: Carrier Phase: Difference between P2 (scaled to L1) & CA channel measurements, in L1 cycles pseudo-range: Difference between P2 & CA ranges in CA chips Quadratic Fit: Recoverable from phase, doppler & doppler rate Phase Residuals from Quadratic Fit: Difference between actual phase value & quadratic fit for the particular phase type available.

Units	Time: Seconds Phase: Cycles
System	Quadratic Fit Point: Receiver Clock Time
Resolution	KBR phase data: 0.1 sec GPS-OD phase data: 1 sec (tau: 30 second) GPS-OCC phase data: 0.02 sec
Inputs	N/A
Data Volume	KBR data: 4.5 Mbytes/day/satellite (average) GPS-OD data: 15.3 Mbytes/day/satellite (average) GPS-OCC data: 25 Mbytes/day/satellite (average)
Data Format	KBR phase data: “10-Second Quad-Fit Packet” format GPS-OD phase data: “30-Second Quad-Fit Packet” format OCC phase data: “1-Second Quad-Fit Packet” format
Latency	As per data dump schedule
Notes	Ref: **QuadraticFitObservables** packet in IPU Spec (327-540)

VI.3.2 Star Camera Assembly Data

Product Identifier	**SCAAttitude**
Product Definition	Data packets containing: • Time of solution • Star camera head ID, data flags & confidence of solution • Star camera quaternion solution
Representation	Quaternions: 4-Elements from each SCA (I/J/K elements of quaternion rotation axis * sin(μ/2); and cos(μ/2) element of quaternion * 2147483648.0)
Units	Solution Time: Seconds
System	Solution Time: Receiver Clock Time
Resolution	Prime Star Camera Quaternions: 1.0 seconds Secondary Star Camera Quaternions: 1 second (variable)
Inputs	N/A
Data Volume	3.5 Mbytes/day/satellite
Data Format	*Fixed Point Long (4 bytes):* Solution time & quaternions
Latency	As per data dump schedule
Notes	The prime and secondary SCA are selected from ground command. Ref: **SCAAttitude** packet from IPU Spec (327-540)

VI.3.3 IPU Navigation Solution

Product Identifier	**AntennaState**
Product Definition	Data packets containing the IPU navigation solution, including • Solution Time • Chi-Squared & Covariance Precision Multiplier • Raw clock steering voltage • Receiver position & offset between GPS & Receiver time • Formal error in receiver position & time offset • Receiver velocity & time offset rate • Formal error in receiver velocity & time offset rate • PRN's used in solution, including their azimuth & elevation values
Representation	N/A
Units	Solution Time: Seconds Position & Velocity: m and m/second Time offset & offset rates: seconds & sec/sec Others: Dimensionless
System	Solution Time: Receiver Clock Time Position & Velocity: WGS-84
Resolution	60 seconds (all data)
Inputs	N/A
Data Volume	32 Kbytes/day/satellite
Data Format	*IEEE Double (8 bytes)*: Position, Velocity, Time Offset & Time Offset Rate *IEEE Float (4 bytes):* All others
Latency	As per data dump schedule
Notes	Ref: **AntennaState** packet from IPU Spec (327-540)

VI.3.4 IPU Housekeeping Data

Product Identifier	**ADC**
Product Definition	Data packets containing the onboard sensor values that may be temperature or voltage or calculated currents
Representation	(TBC)
Units	Volts, °C
System	N/A
Resolution	≈ 400 sec
Inputs	N/A
Data Volume	< 10 Kbytes/day
Data Format	(TBC)
Latency	As per data dump schedule
Notes	Ref: **ADC** packet in IPU Spec (327-540)

VI. 4 HOUSE-KEEPING APPLICATION PACKETS

This section describes the contents of some of the relevant Application Packets available in the spacecraft housekeeping data stream. These data may be generated by either the spacecraft payloads or subsystems (with the exception of the IPU and the ICU), or by the on-board software.

VI.4.1 Time Stamp Packet

Product Identifier	**TimeStamp**
Product Definition	Data packets containing the spacecraft elapsed time (SCET) or GPS time estimate, corresponding to the 1 Hz synchronization pulse on the satellite. • Time Flag: whether SCET or GPS Time is provided • Time Estimate
Representation	N/A
Units	Time Estimate: Seconds
System	Time Estimate: SCET since boot-up or GPS Time, in seconds since Jan 6, 1980.
Resolution	1 second
Inputs	N/A
Data Volume	0.7 Mbytes/day
Data Format	Time: 4 bytes
Latency	As per data dump schedule
Notes	This packet is interleaved into the telemetry data stream at the start of every one second, such that all data packets between two time stamp packets may be assigned logically the time of the first time stamp. Ref: **TimeStamp** packet, Sections 2.8.4, 6, 3.6.3.2, 3.6.8.2 in Onboard Software Data Interfaces & Data Flow (GR-DJO-SW-0002 – Iss 1.0).

VI.4.2 AOCS Default H/K Data

Product Identifier	**AOC_DEFHK**
Product Definition	• Thruster on-time commanded by the AOCS during current OBDH work cycle • Satellite angular rates estimated from IMU (Gyro)
Representation	• Thruster on-time: Signed integer along 3 axes: The sign determines uniquely the thrusters to be activated; the magnitude is the on-time. • Satellite Rates: Fixed (in steps of 10 microRad/sec) Time-tag determined by previous TimeStamp packet. This information is part of a larger AOCS H/K packet.
Units	On-Time: milli-seconds
System	Time: Receiver Time Rates: Satellite Frame relative to inertial
Resolution	3 second (average, if every 3rd packet is available)
Inputs	N/A
Data Volume	2.5 Mbytes/day/satellite
Data Format	Packaged as part of AOCS H/K
Latency	As per data dump schedule
Notes	Ref: **AOC_DEFHK** packet, Section 7.1.4.1 in Onboard Software User Manual (GR-DJO-SW-0005 – Issue 1.2).

VI.4.3 Cumulative Thruster On-Time Data

Product Identifier	**AOC_STAT**
Product Definition	• Cumulative number of activations for each thruster • Cumulative on-time for each thruster • TimeStamp of most recent thruster activation
Representation	Time tag determined by previous TimeStamp packet.
Units	Times: milli-seconds
System	Time: Receiver Time
Resolution	9 second (if every 9th packet is available)
Inputs	N/A
Data Volume	1 Mbyte/day/satellite
Data Format	This information is part of a larger AOCS H/K packet.
Latency	As per data dump schedule
Notes	Ref: **AOC_STAT** packet, Section 7.1.4.1 in Onboard Software User Manual (GR-DJO-SW-0005 – Issue 1.2).

VI.4.4 Satellite Thermistors Data

Product Identifier	**ANARAW_SCT & ANARAW_HRT**
Product Definition	• Standard calibration thermistor measurements • High resolution thermistor measurements
Representation	Time tag determined by previous TimeStamp packet
Units	Temperature: °C
System	Time: Receiver Time
Resolution	90 second (if every 9th packet is available)
Inputs	N/A
Data Volume	0.3 Mbytes/day/satellite
Data Format	Temperatures:
Latency	As per data dump schedule
Notes	Ref: **ANARAW_SCT** & **ANARAW_HRT** packets, Sections 4.2.2, 4.2.3.1, & 4.2.3.2 in Onboard Software Data Interfaces & Data Flow (GR-DJO-SW-0002 – Iss 1.0).

VI.4.5 Magneto-Torquer & Magnetometer Data

Product Identifier	**MAG**
Product Definition	• X/Y/Z measured components of Earth magnetic fields • Magnetorquer currents
Representation	Time tag determined by previous TimeStamp packet
Units	MAG: nano-Tesla MTQ currents: Amps
System	Time: Receiver Time MAG: In Satellite Frame
Resolution	60 second (if every 6^{th} packet is available)
Inputs	N/A
Data Volume	0.1 Mbytes/day
Data Format	N/A
Latency	As per data dump schedule
Notes	Ref: **MAG** packet, Sections 4.2.2, & 4.5.3 in Onboard Software Data Interfaces & Data Flow (GR-DJO-SW-0002 – Iss 1.0).

LIST OF ACRONYMS

A

ACC	Accelerometer
ADC	Analog-Digital Converter
AOCS	Attitude & Orbit Control System

B

C

D

DFD-NZ	German Remote Sensing Data Center, Neustrelitz
DLR	Deutsches Zentrum für Luft und Raumfahrt

E

F

G

GFZ	GeoForschungsZentrum Potsdam
GPS	Global Positioning System
GRACE	Gravity Recovery And Climate Experiment

H

I

ICRF	International Celestial Reference Frame
ICU	Interface & Control Unit
IERS	International Earth Rotation Service
IGS	International GPS Service
IMU	Inertial Measurement Unit
IPU	Instruments Processing Unit
ITRF	International Terrestrial Reference Frame

J

JPL	Jet Propulsion Laboratory

K

KBR	K-Band Ranging System

L

M

N

O

OBDH	On-Board Data Handler

P

PODAAC	Physical Oceanography Distributed Data Archive
PCDU	Power Conditioning and Distribution Unit

Q

R

RDC	Raw Data Center

S

SCA	Star Camera Assembly
SDS	Science Data System
SLR	Satellite Laser Ranging
SU	Sensor Unit (ACC)

T

TBC	To Be Confirmed
TBC	To Be Completed
TBD	To Be Done

U

USO	Ultra-Stable Oscillator
UTC	Coordinated Universal Time
UTCSR	University of Texas Center for Space Research