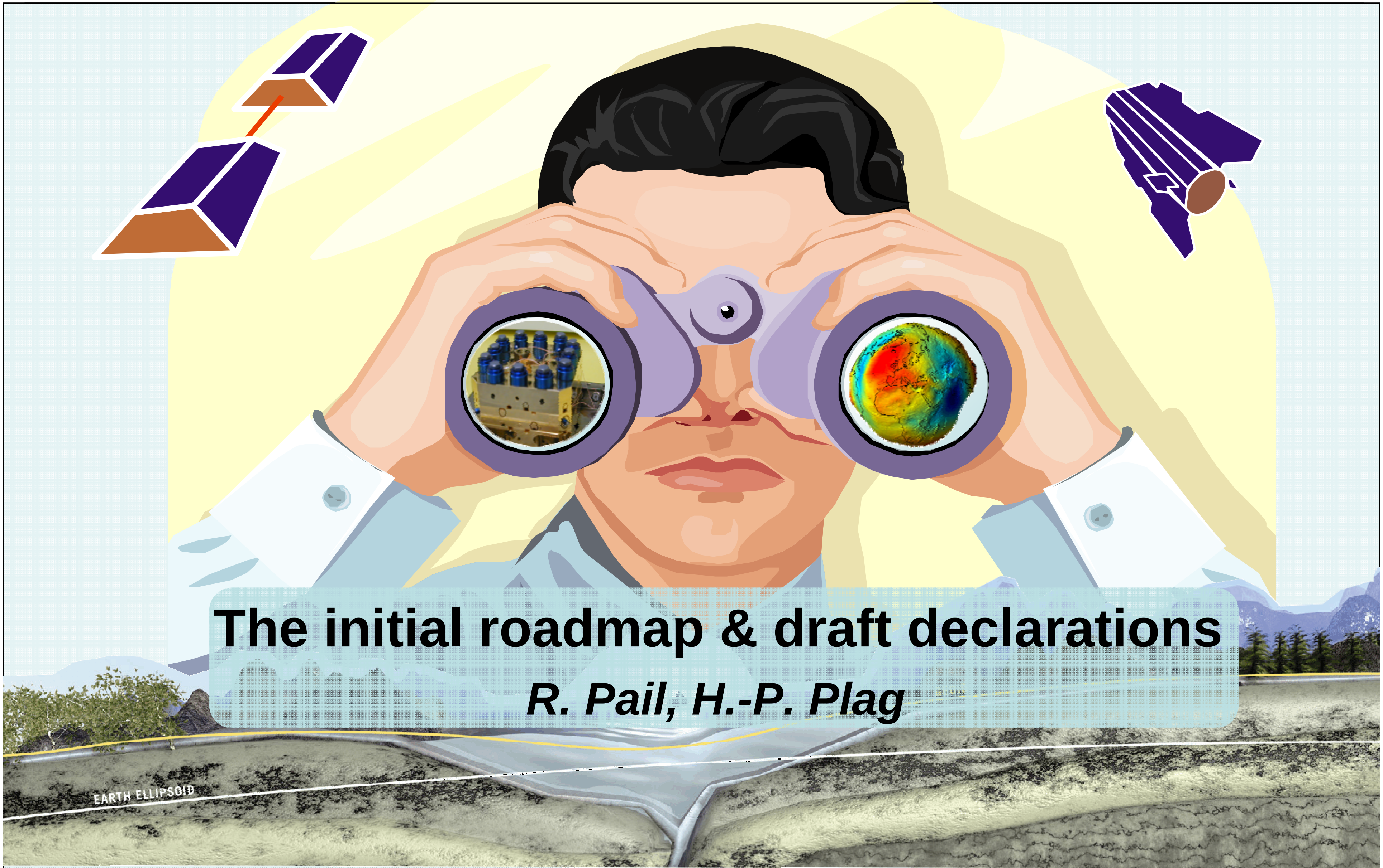


The initial roadmap & draft declarations

R. Pail, H.-P. Plag

Workshop output

Document		**Due date**
Roadmap	draft version final version	02-10-2009 15-10-2009
Resolutions	consolidated	02-10-2009
Declarations	consolidated	02-10-2009
Workshop report		15-11-2009
Summary report in Episodes		TBD
Thematic issue of *Physics and Chemistry of the Earth*		TBD

Resolutions

Resolutions from the
Workshop on The Future of Satellite Gravitmetry,
12–13 April 2007, ESTEC; Noordwijk

The Future of Satellite Gravimetry

Report from the

Workshop on The Future of Satellite Gravimetry

12-13 April 2007, ESTEC, Noordwijk, The Netherlands

Radboud Koop and Reiner Rummel (Eds.)

1

GRACE is demonstrating very successfully to provide monthly time series of changes in the Earth's gravity field. This adds a new – and very central – parameter set to the study of Global Change phenomena such as deglaciation in the large ice shields of Antarctica and Greenland or the variations of the global water cycle.

Proposal:

Statement on the value of GRACE and its impact in geosciences, including a non-exhaustive list of examples in diverse fields of application, but also current limitations.

→ B1, B5, B6

2

GOCE – to be launched 2008 – is expected to deliver the global static gravity field and geoid with unprecedented precision and spatial resolution. It will in particular serve as reference for global ocean circulation studies by altimetry.

Proposal:

Updated statement on the GOCE status, expected gain with respect to GRACE, and expected impact.

→ B1, B2, B5, B6

3a In view of science achievements and the current performance of GRACE the participants of the workshop strongly support the idea of a GRACE follow-on mission based on the present configuration, with emphasis on the uninterrupted continuation of time series of global gravity changes. This should be short-term (Launch ~2011 TBD) priority one.

Seed questions:

- How can we support the initiative on the GRACE follow-on mission?

→ B1 – B6

3b In parallel, investigations into the reduction of the aliasing problem offers even greater science benefits by increased spatial resolution and accuracy and should therefore have high priority.

Seed questions:

- What is the status of investigations related to the problems of aliasing and distortions, what are the conclusions?
- Have we significantly increased the insight into these problems since 2007?
- What are possible (and realistic) scenarios to solve/reduce these problems, and what is their expected qualification time?

→ B2, B3, B4

4 Medium term priority should be focused on higher precision and higher resolution in space and time. This step requires (1) the reduction of the current level of aliasing (of high frequency phenomena, in particular tides, into the time series), (2) the elimination of systematic distortions (caused by the peculiar non-isotropic sensitivity of a single pair low-low SST), and (3) the improvement of the separability of the observed geophysical signals.

Elements of a strategy in this direction are configuration flights, multi-satellite systems, improved data processing methodologies and improved and comprehensive Earth System modeling.

This will open the door to a more efficient use of improved sensor systems, such as optical ranging systems, quantum gravity sensors, and active angular and drag-free control.

Seed questions:

- What is the scientific progress since 2007?
- How large are the relative contributions of …

4 Medium term priority should be focused on higher precision and higher resolution in space and time. This step requires (1) the reduction of the …

Seed questions:

- What is the scientific progress since 2007?
- How large are the relative contributions of
  - sensor system (noise level, anisotropic error behaviour, …)
  - inaccurate knowledge of background models
  - spectral and temporal aliasing
  - processing errors
  - supporting technologies (tracking systems, accelerometers, drag-free systems)
- Do we need a consistent Earth system model to fully exploit space gravity observations (role of hydrology, oceans, atmosphere; separability) ?
- How can we involve experts of supporting sciences more prominently in our discussion?

→ B1 – B6

5 The long term strategy should include the gravimetric use of advanced clocks (ground based and flying clocks), micro-satellite systems, and space-qualified quantum gravity sensors.

Seed questions:

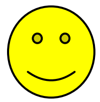
- What is the status and scientific progress of those new technologies?
- Which of these technologies are not / less affected by the problems we are currently dealing with?

→ B2, B4

6 The participants of the workshop support the activities and developments towards a future satellite gravity mission.

Proposal:

- I hope we will find a majority for this statement!



→ all

7 The workshop results will be offered to national and international space agencies and other relevant institutions.

Proposal:

- We should also think about a dissemination strategy during this workshop.

→ B6

8 The initiative will be taken to set up an international steering/working group or platform to coordinate the future activities and actions in this field.

Seed questions:

- Shall we take concrete steps to install such an international steering/working group?
- If yes, how can we organize it most efficiently?
- Which should be the institutional platform of such a working group, also for the purpose of legitimation?

Who is prepared and willing to join?

9

Links between the geodetic and Earth science community with the communities from fundamental physics will be strengthened and/or established.

Evaluation:

- This statement is answered positively by the list of participants of this workshop!

Seed questions:

- Which additional statements are required for the new resolutions?
- TBD

→ all

Roadmap

Inventory from the
Workshop on The Future of Satellite Gravitmetry,
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IAS

Accuracy requirements

- static

Table 3-1: Static gravity field, scientific requirements in preparation for GOCE, from: Rummel (2005).

Static gravity field, scientific requirements in reparation for GOCE					
Application			Accuracy		Spatial resolution
			Geoid [cm]	Gravity [mGal]	Half wavelength D [km]
Solid Earth	Lithosphere/upper mantle density			1-2	100
	Continental lithosphere	Sedimentary		1-2	50-100
		Basins rifts		1-2	20-100
		Tectonic motions		1-2	100-500
	Seismic hazards			1	100
	Ocean lithosphere/asthenosphere			0.5	100-200
Oceanography	Short scale		1-2		100
			0.2		200
	Basin scale		~0.1		1000
Ice sheets	Rock basement			1-5	50-100
	Ice vertical movements		2		100-1000
Geodesy	Levelling by GPS		1		100-1000
	Unified height system		1		100-20000
	INS			~1-5	100-1000
	Orbits			~1-3	100-1000
Sea level change			Many of the above applications, with their specific requirements, are relevant to studies of sea level change.		

- temporal

Table 3-2: Accuracy requirements.

Application	mm_{H2O}/mon	mm_{H2O}/yr	smoothing radius (km) ≥ 300	Timescales and Notes
Hydrologic basin total water change	10	20 (10)	400	days to decades
Glacier mass loss		2 (1)	300	seasonal, interannual
Ice sheet mass loss		20 (5)	1,000	
Oceanic gyres spinup or down		4 (1)	700	interannual
Global Sea level rise: thermosteric / eustatic		1 (0.3)	5,000	seasonal, interannual
Glacial Isostatic Adjustment		0.5 (0.1)	1,000	5-10 years

Candidate technology

- gravity sensors

Table 6-1: Gravity Sensors and Their Status of Development.

	Status	Expected qualification time*
Microwave interferometer	Flight proven (TRL9)	-
Inter-spacecraft Laser interferometer: Master-slave (2 lasers) Master+retro-reflector(1 laser)	 Qualified prototype (TRL6) Breadboard (TRL4)	 1-2 years 2-4 years
Gradiometer: Electro-static LTP Optical test mass readout Quantum Cryogenic	 Flight qualified (TRL8) Launch in 2010 (TRL7) Breadboard (TRL3) Breadboard (TRL3)	 - 1 year 15 years undefined (unfit for mission)
Drag-free low-low SST: LTP Gravity Reference Sensor One-axis Ion Thrusters 5-DoF FEEP Thrusters	 Launch in 2009 (TRL7) Flight Proven (TRL 9) Launch in 2009 (TRL 5)	 1 year - 3 years
Optical clock	Qualified prototype (TRL6)	15 years

- supporting technology

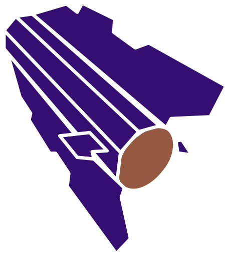
Table 6-2: Supporting Technology for Future Gravimetric Satellite Missions.

	Status	Expected qualification time
Tracking system: GPS GLONASS GALILEO	 Flight proven (TRL9) Flight proven (TRL9) Prototype (TRL5)	 - 1-2 years *
Electric propulsion: Ion engine (high thrust) FEEP (low thrust)	 Flight qualified (TRL8) Qualified prototype (TRL6)	 - 2-4 years
Accelerometer 10^{-10} ms-2 Accelerometer 10^{-12} ms-2	Flight proven (TRL9)** Flight qualified (TRL8)**	- -
LISA/LTP inertial sensor 10^{-14} ms^{-2}	Launch in 2010 (TRL7)	1 year

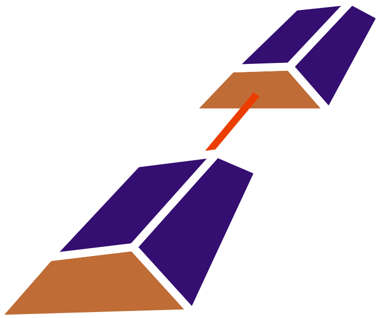
Roadmap: Key elements of matrix of mission concepts

Gravity sensor / formation

- Mission (user) requirements
- Expected performance
- Pros & cons of mission concept



- Level of technological maturity (TRL)
- Expected qualification time
- Level of readiness of supporting science



- Remaining scientific challenges and expected solution time
- Complementarity with and need of other data sources
- Cost estimates
- Prioritization ($\rightarrow$ baseline strategy)

Charge to the Breakout Sessions

Wednesday

Time			
09:00 – 10:40	**P1**: Status, Requirements and Challenges		
10:40 – 11:00	Coffee Break		
11:00 – 11:20	Introduction to Breakout Sessions		
11:20 – 12:40	**B1** A306 Mission requirements	**B2** BE01 Mission design	**B3** A111 Data proc., modelling & interpret.
12:40 – 14:00	Lunch (buffet)		
14:00 – 15:40	**B1** A306 ctd‘	**B2** BE01 ctd‘	**B3** A111 ctd‘
15:40 – 16:00	Coffee Break		
16:00 – 16:30	**P2a**: Reports from the Breakout Sessions		
16:30 – 18:00	**P2b**: The Space Agencies: Programs and Boundary Conditions		
19:00 – 21:00	No-Host Dinner		

Charge to the Breakout Sessions

B1: **Mission requirements**	**3rd floor**
Co-chairs: Bert Vermeersen, Victor Zlotnicki	**A306**
B2: **Mission design**	**this room**
Co-chairs: Jürgen Müller, Stefano Cesare, Nico Sneeuw	**BE01**
B3: Data processing, modelling and interpretation	**1st floor**
Co-chairs: Frank Flechtner, Srinivas Bettadpur	**A111**

- Contributions to roadmap
- Contributions to resolutions
- Contributions to declarations
- Contributions to workshop report

Equipment

B1: **Mission requirements** *Co-chairs: Bert Vermeersen, Victor Zlotnicki*	**3rd floor** **A306**
B2: **Mission design** *Co-chairs: Jürgen Müller, Stefano Cesare, Nico Sneeuw*	**this room** **BE01**
B3: Data processing, modelling and interpretation *Co-chairs: Frank Flechtner, Srinivas Bettadpur*	**1st floor** **A111**

All rooms are equipped with:

- fixed projector connected with presentation notebook
- mobile projector (optionally: e.g. for minutes)
- blackboard