



## ***The GOCE High Level Processing Facility***

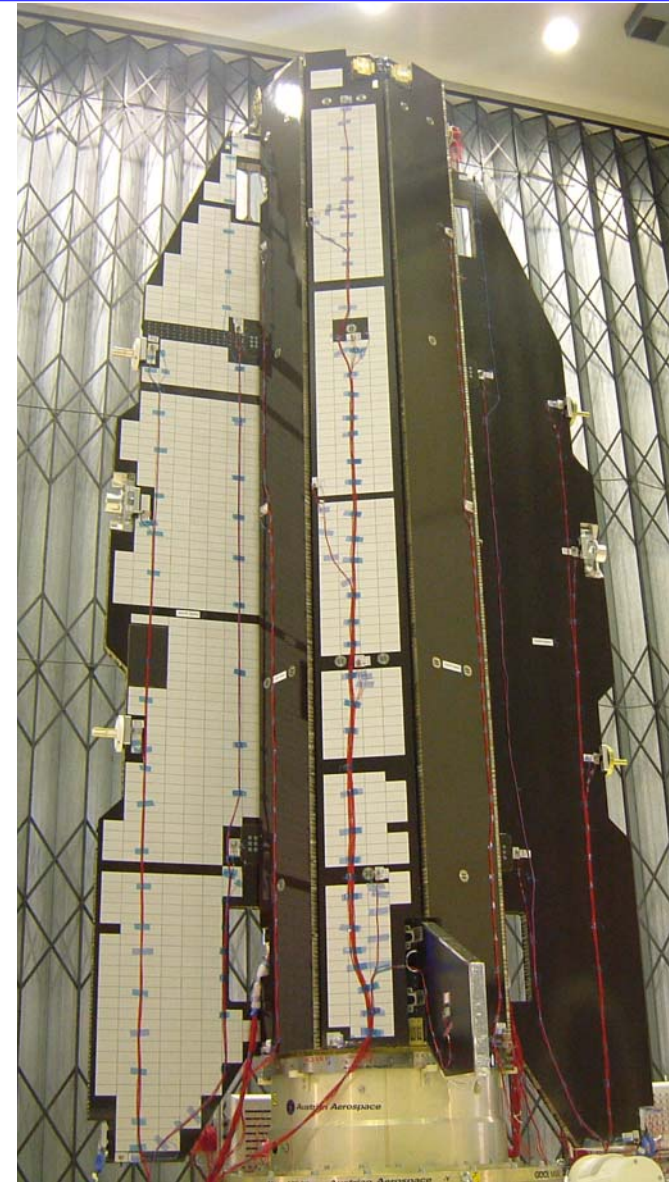
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**<sup>1</sup> Institut für Astronomische und Physikalische Geodäsie, Technische Universität München**

**<sup>2</sup> Space Research Organisation Netherlands (SRON)**

# Outline

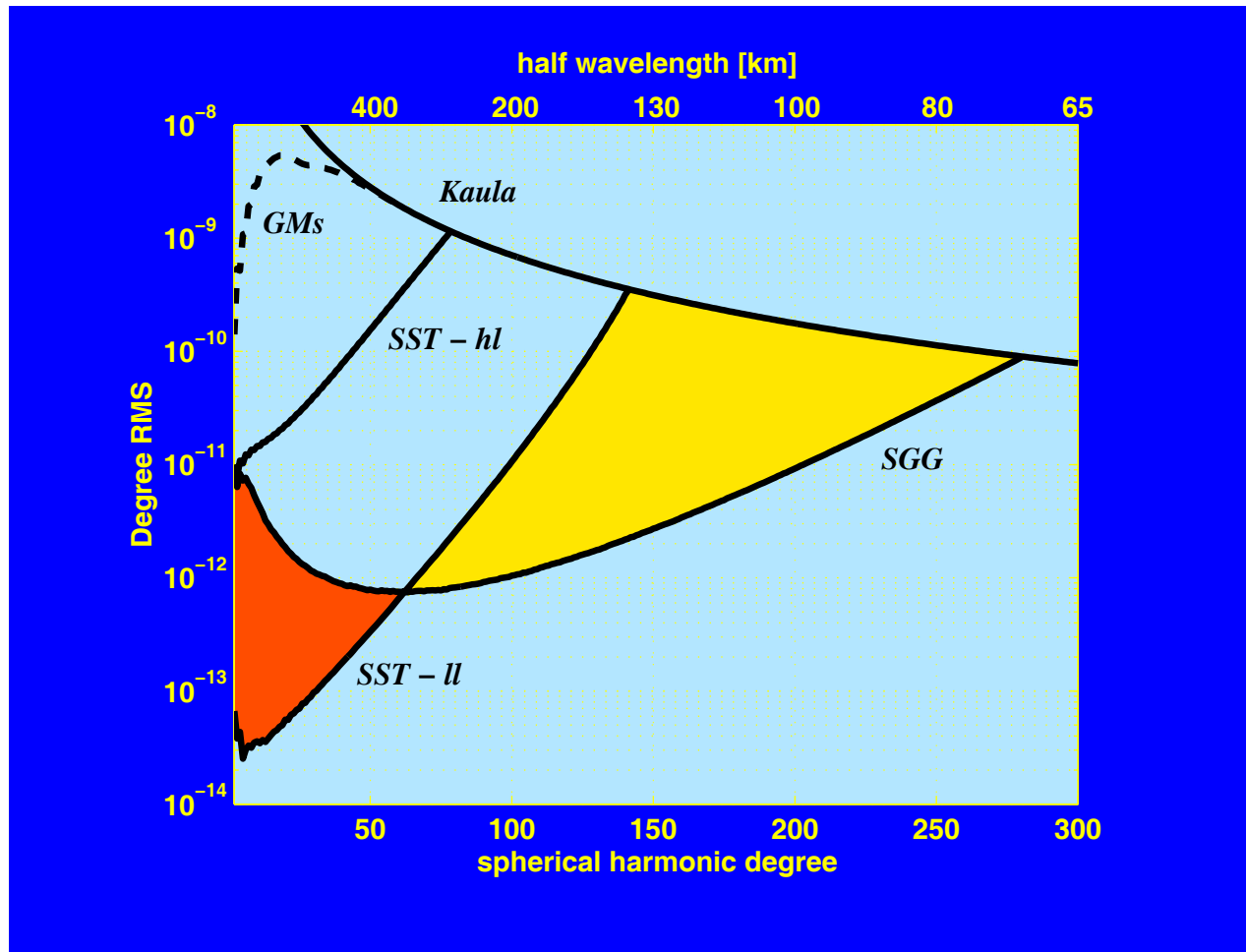
- 1. Overview GOCE-ESA Ground Segment**
- 2. The High Level Processing Facility**
  - Overview**
  - Processing Flow**
  - Gravity Field Processors**
  - Product Validation**
  - Schedule & Products**
- 3. Conclusions**



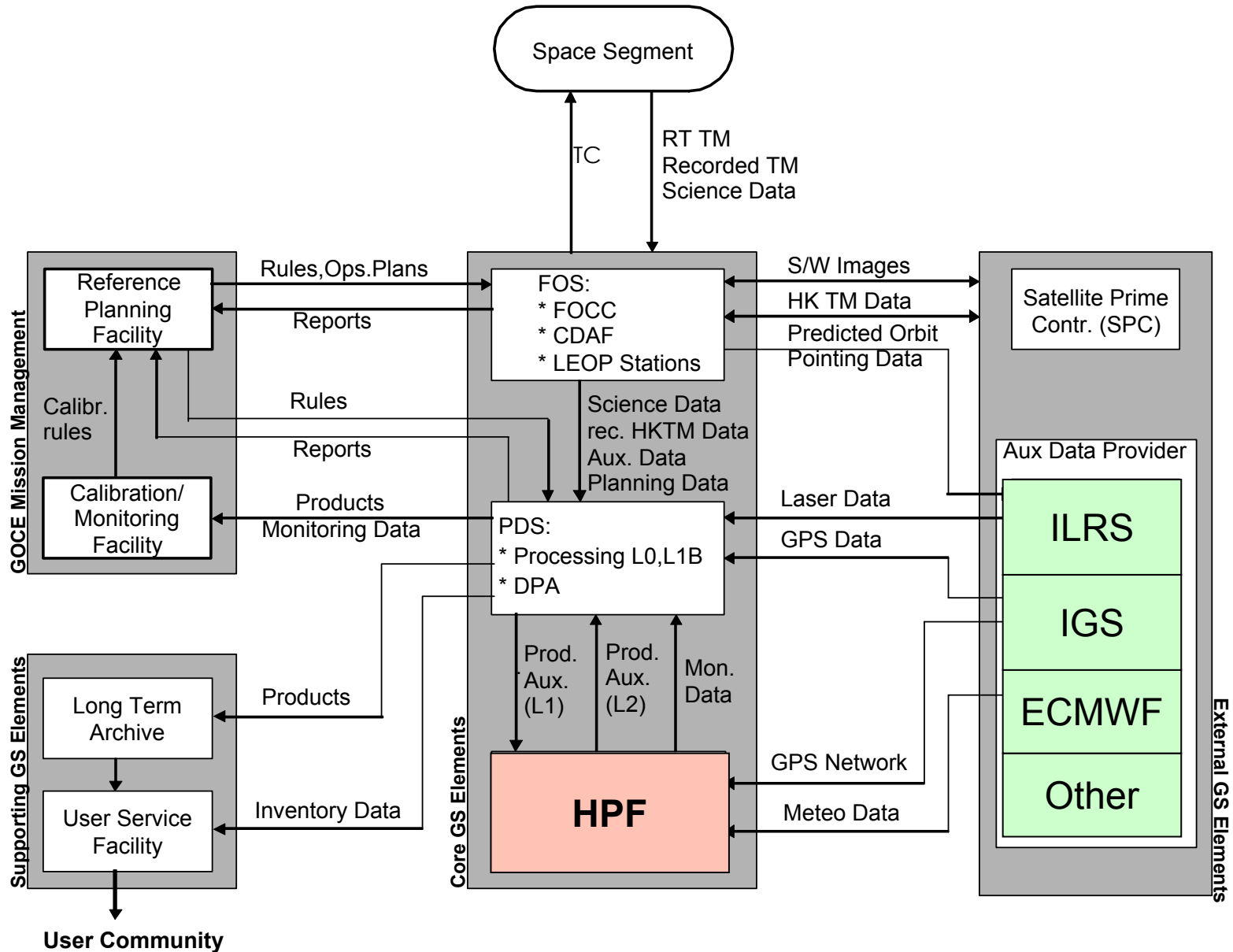
*GOCE Structural Model at  
ESTEC (June 2004)*

# GOCE Mission Goal

***Determination of the Earth Gravity Field by Satellite Gravity Gradiometry and GPS high-low SST with an Accuracy of better than 1 mGal for Gravity Anomalies and 2 cm for Geoid Heights at Degree and Order 200.***



# Overview ESA Ground Segment



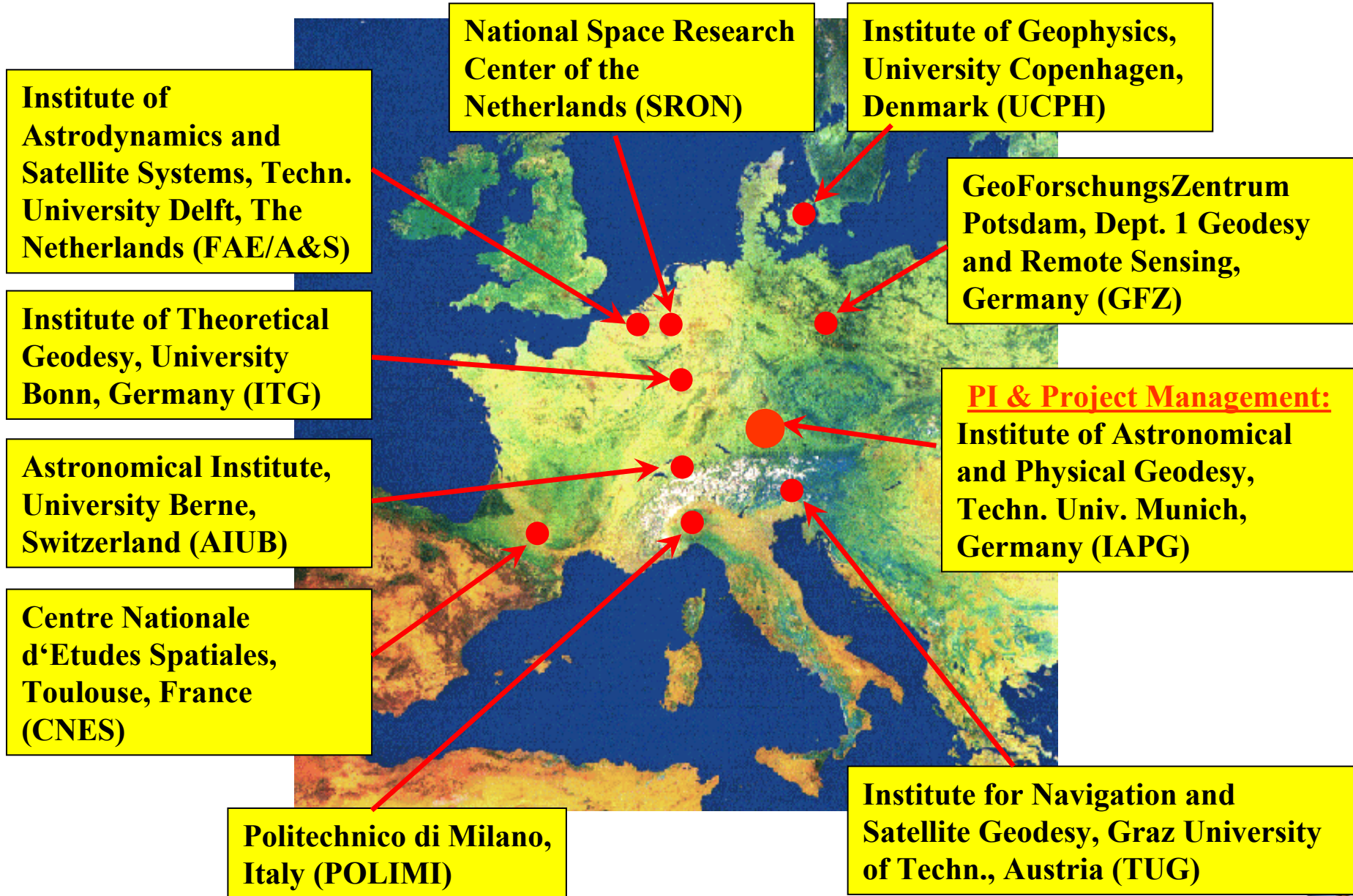
# Tasks of High Level Processing Facility

- Generation of level 2 products from level 1b data from the Payload Data Segment (time series of internal calibrated gravity gradients and GPS data)
- Level 2 products are:
  - External corrected and calibrated instrumental data sets
  - Rapid science orbits and quick-look gravity field models
  - Precise science orbits and final GOCE gravity field models

# Who is the HPF ?

1. The **European GOCE Gravity Consortium (EGG-C)** submitted a proposal to ESA covering the HPF development and operations. The project started in April 2004.
2. EGG-C is composed of 10 European institutes working in the field of gravity field research and orbit determination (see map).
3. The HPF is a **distributed system** composed of a central processing facility (located at SRON) and several sub-processing facilities (located at various institutes of EGG-C members).
4. The HPF is **led by a Principal Investigator** (Reiner Rummel) **and a management team** composed by IAPG (Th. Gruber) and SRON (R. Koop). The main contract for the HPF is signed between ESA and IAPG. High-level work packages are sub-contracted to EGG-C members.

# Who is the HPF ?



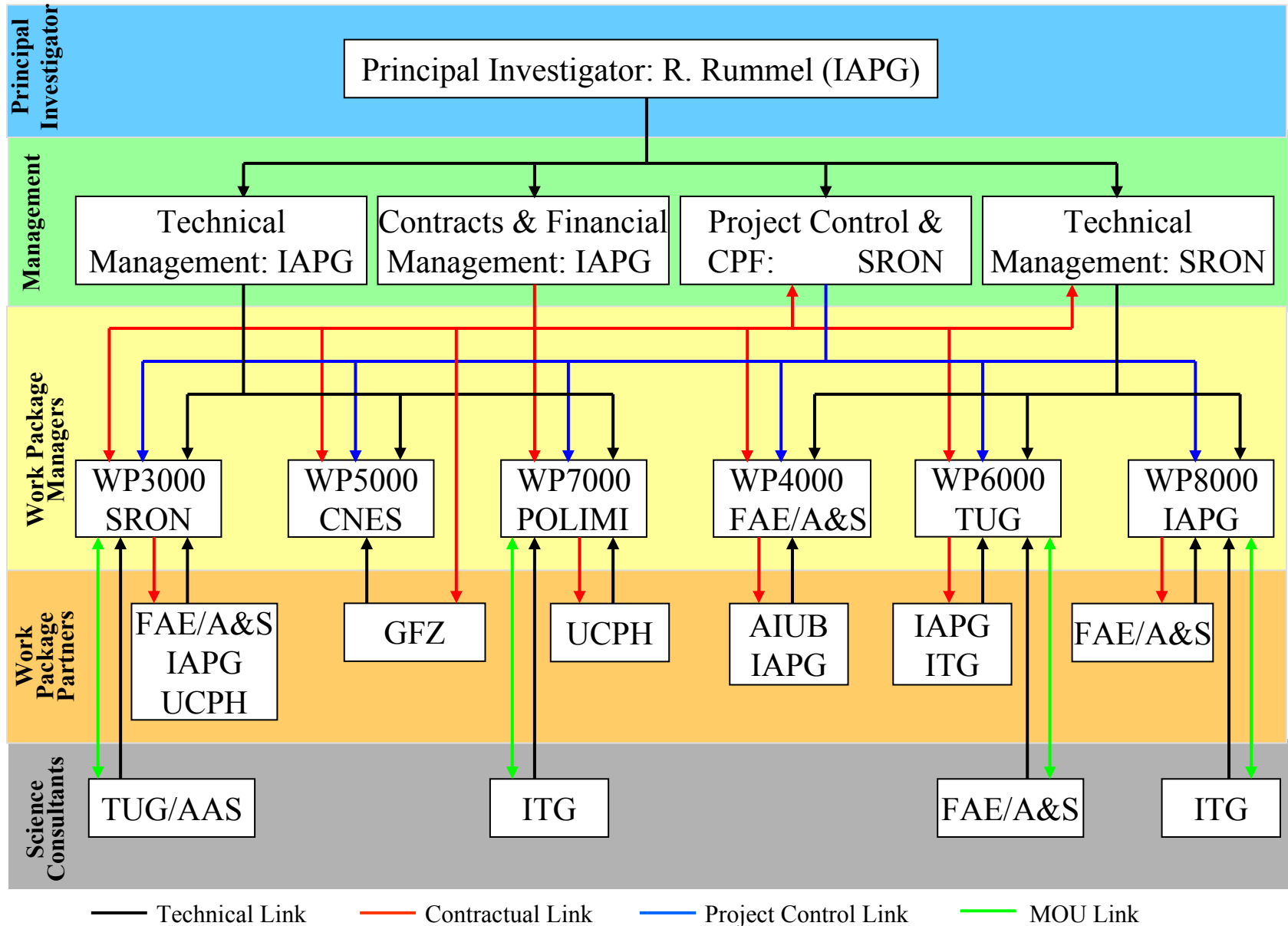
# Who is the HPF ?

The grey Eminences ...

... and their Team



# How is the HPF organized ?



— Technical Link

— Contractual Link

— Project Control Link

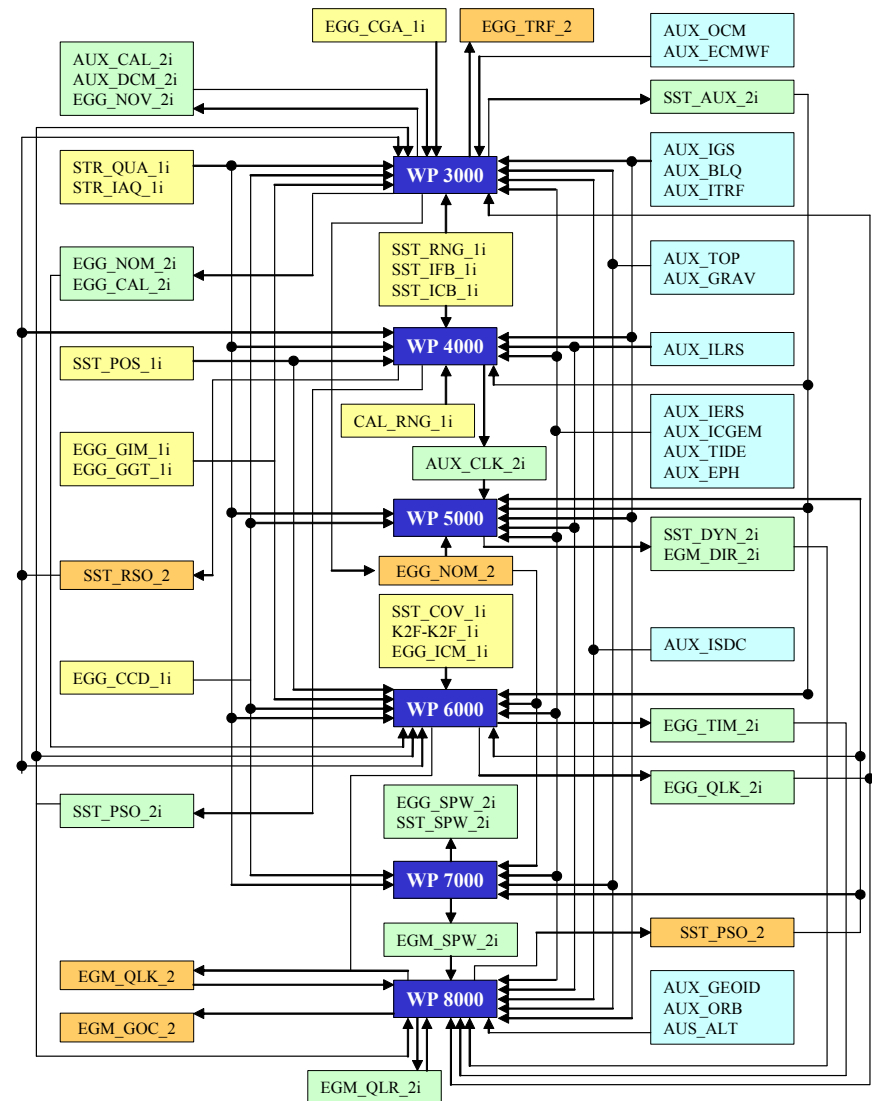
— MOU Link

# What does the HPF ?

WP ID	WP Description	Responsibility
WP3000	<b>Scientific Pre-processing and External Calibration</b> <ul style="list-style-type: none"> <li>• Gradiometer External Calibration</li> <li>• Corrections for Temporal Gravity (tidal &amp; non-tidal)</li> <li>• Data Screening and Data Gaps</li> </ul>	SRON
WP4000	<b>Orbit Determination</b> <ul style="list-style-type: none"> <li>• Rapid Science Orbits (kinematic &amp; reduced dynamic)</li> <li>• Precise Science Orbits (kinematic &amp; reduced dynamic)</li> </ul>	FAE/A&S
WP5000	<b>Gravity Field Determination – Direct Approach</b> <ul style="list-style-type: none"> <li>• SST: Orbit Perturbation; SGG: Normal Equations</li> <li>• Combination by Normal Equations</li> </ul>	CNES
WP6000	<b>Gravity Field Determination – Time-wise Approach</b> <ul style="list-style-type: none"> <li>• SST: Energy Conservation; SGG: Semi-Analytical &amp; Normal Equ.</li> <li>• Combination by Normal Equations</li> <li>• Quick-Look and Precise Solutions</li> </ul>	TUG
WP7000	<b>Gravity Field Determination – Space-wise Approach</b> <ul style="list-style-type: none"> <li>• SST: Energy Conservation; SGG: Wiener Filtering</li> <li>• Combination by Collocation</li> </ul>	POLIMI
WP8000	<b>Level 2 Products Validation</b> <ul style="list-style-type: none"> <li>• Extensive Validation Reports, Recommendation of Final Products by independent committee.</li> </ul>	IAPG

# HPF Processing Strategy

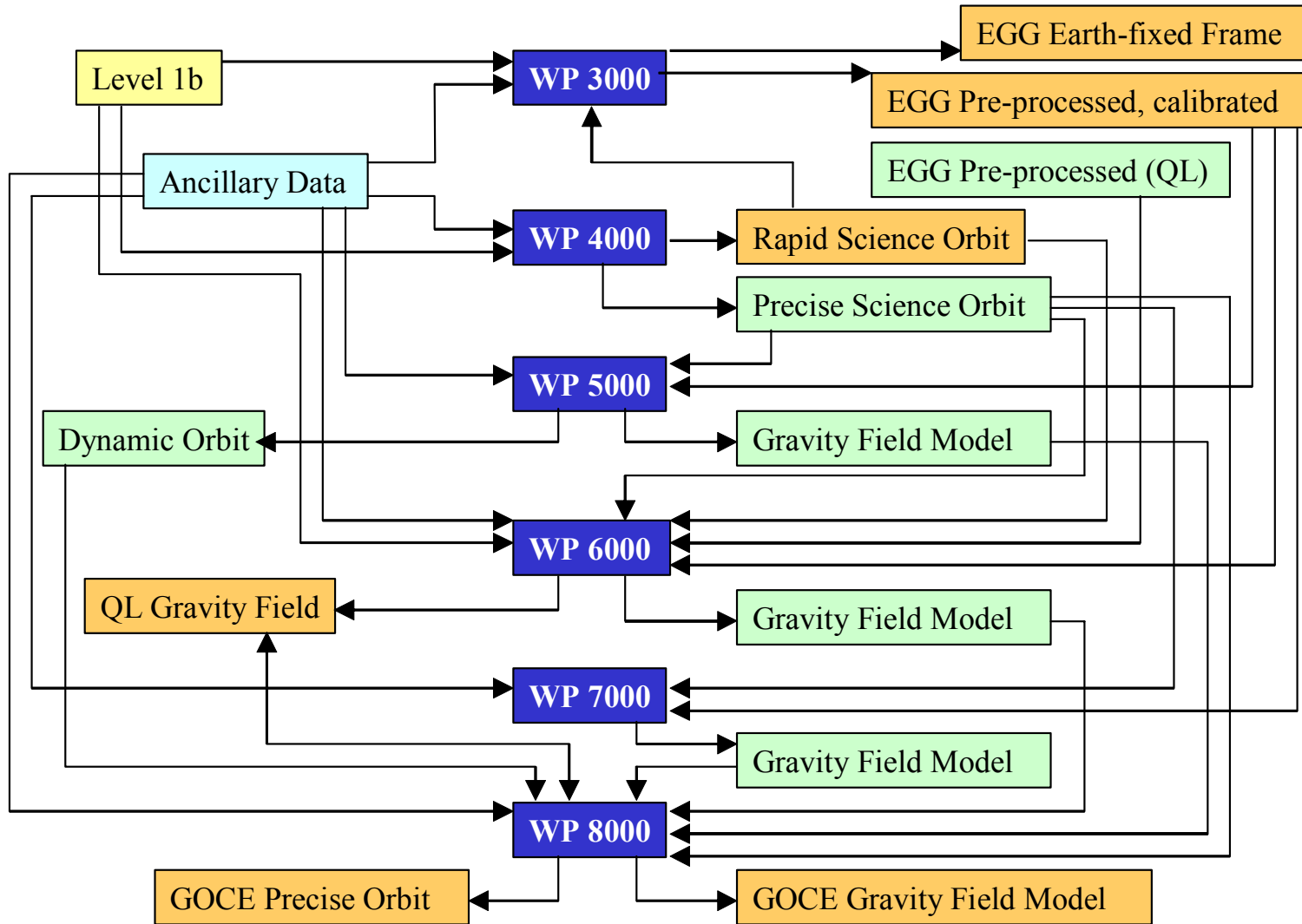
1. The HPF will use **all level 1b** data and a **variety of ancillary data** for generation of level 2 products.
2. **Intermediate level 2 products** will be generated in all work packages. In most cases they are used as input for another work package.
3. Level 2 products are divided into **quick-look products** targeting for a low latency with reasonable accuracy and **final products** targeting for ultimate precision.



Level 1b Input Products
Level 2 Ancillary Products
Level 2 Intermediate Products
Level 2 Final Products

● = Dots mark ramifications from ambiguous arrows

# HPF Processing Strategy – Simplified View



Level 1b Input Products

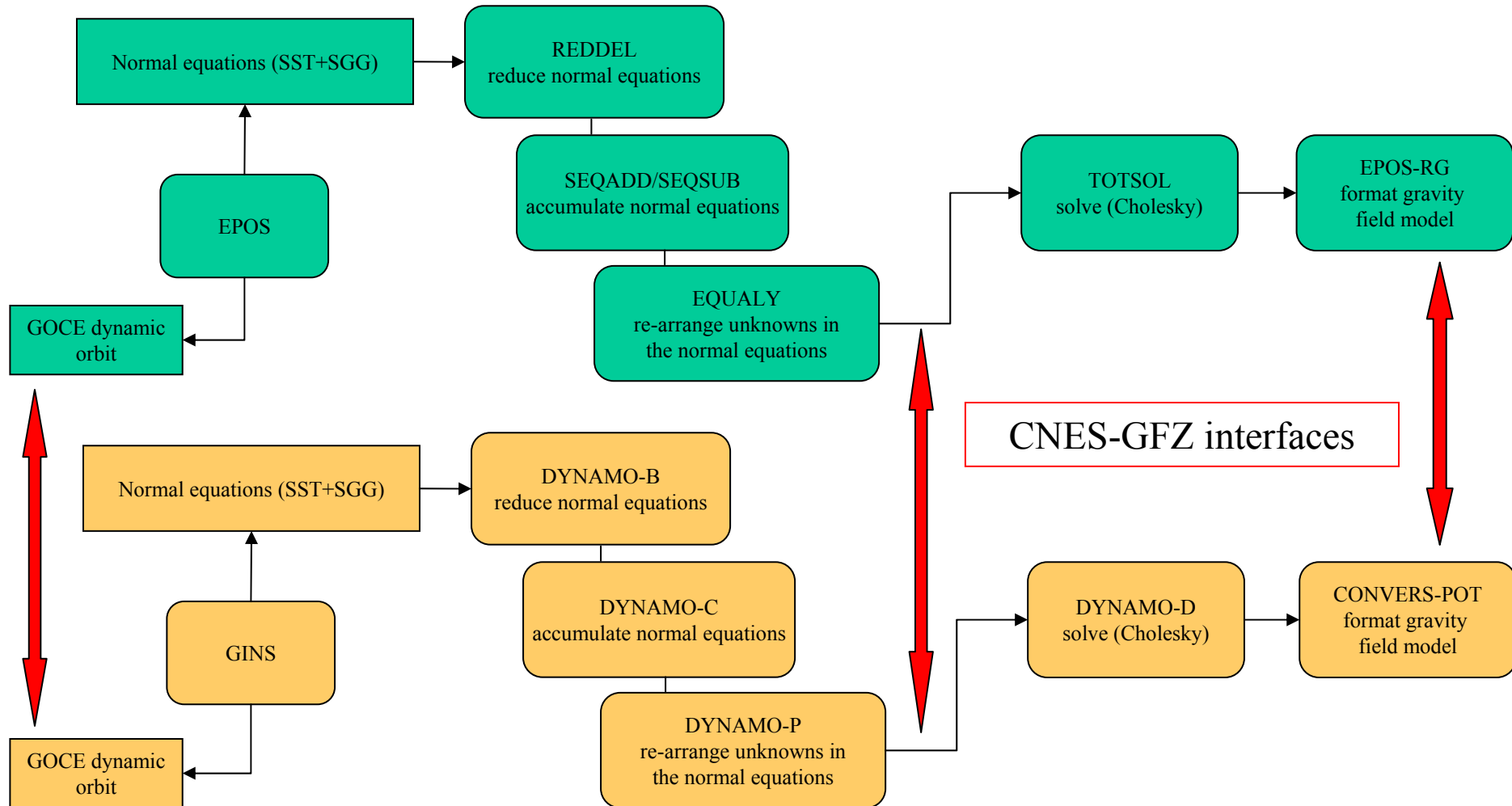
Level 2 Ancillary Products

Level 2 Intermediate Products

Level 2 Final Products

# WP5000 Gravity Field Determination

## Direct Approach: CNES & GFZ Software Architecture



# WP6000 Gravity Field Determination

## Time-Wise Approach: TUG & IAPG & ITG Software Architecture

### QL-GFA:

#### Quick-Look Gravity Field Analysis

- SST: Energy conservation
- SGG-only: Analysis of residuals & Error model
- SST, SGG, SST+SGG Gravity models based on block-diagonal normal equations using an iterative approach.

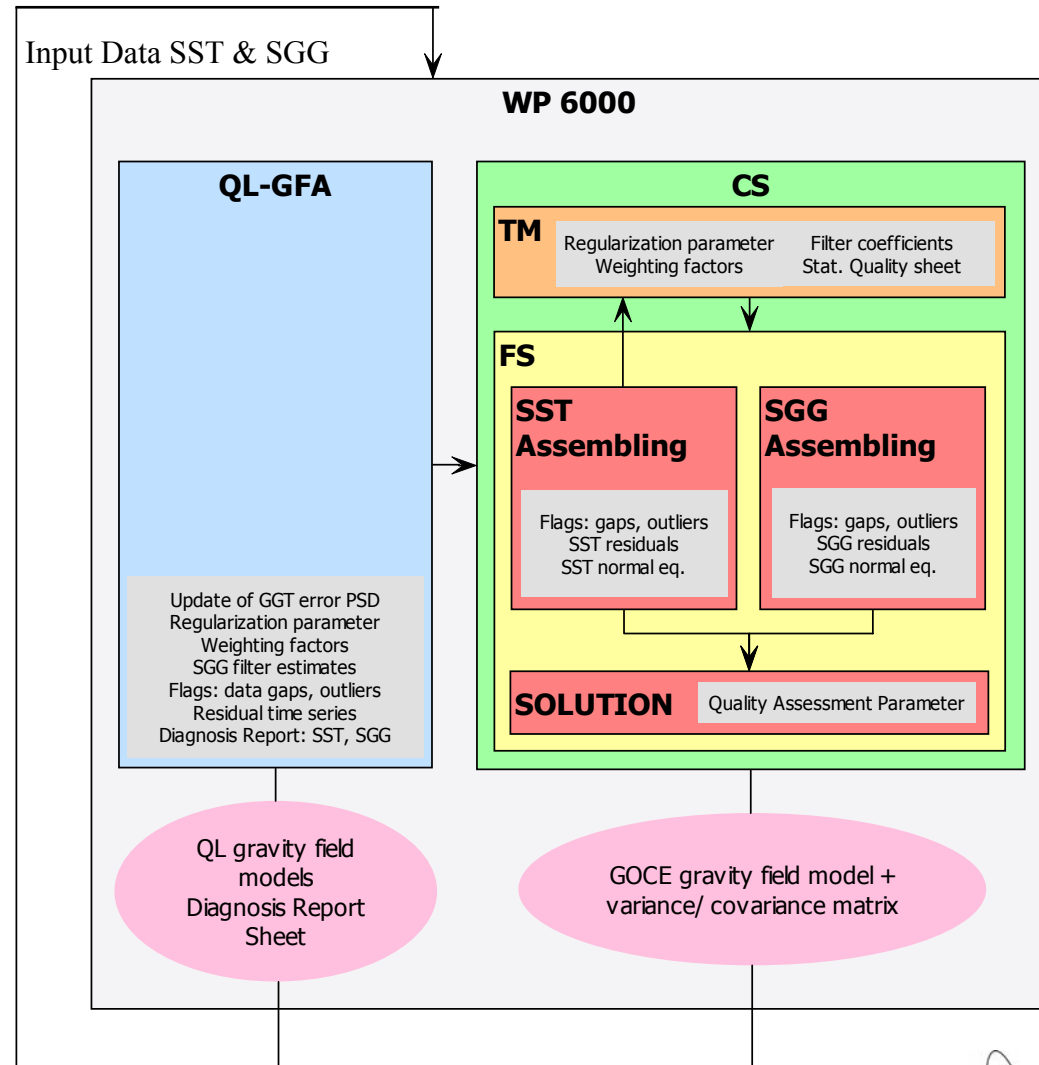
### CS: Core Solver

#### TM: Tuning Machine

- Optimal regularisation and weighting parameters
- Filter design

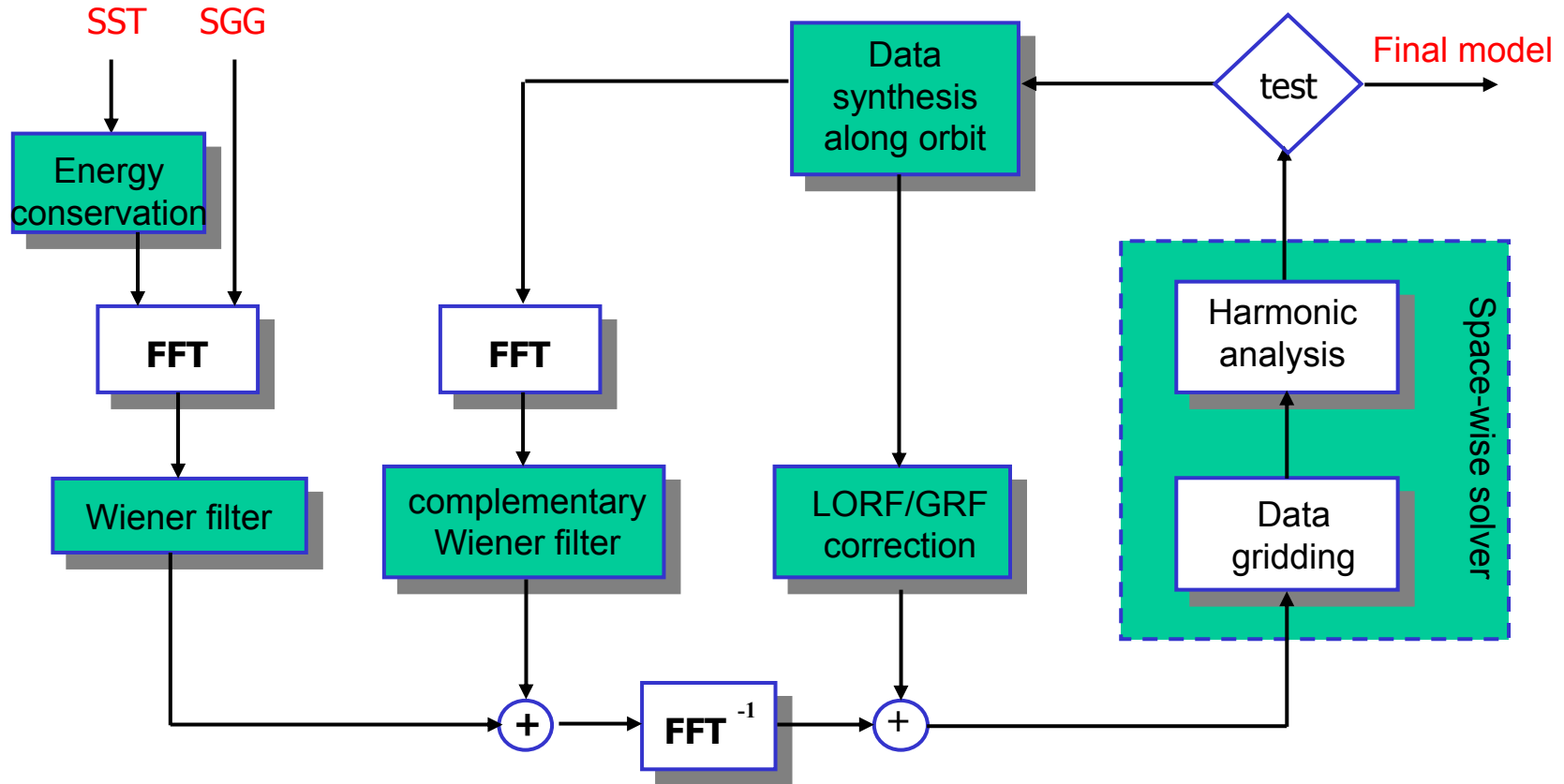
#### FS: Final Solver

- SST: Energy conservation
- SST & SGG: Full normal equation systems



# WP7000 Gravity Field Determination

## Space-Wise Approach: POLIMI & UCPH Software Architecture



**Energy Conservation:** for SST data analysis  
**Wiener Filter:** for joint analysis of SST and SGG observations in frequency domain producing spatialized observations.

**Gridding:** by least squares collocation  
**Harmonic Analysis:** by fast spherical collocation  
**Iterative Scheme:** for recovery of lost signal during filtering and errors in GRF-LORG rotations.

# WP8000 Product Validation

## *Orbit Validation*

<b>Tool</b>	<b>Test Data Sets</b>	<b>Quality Parameters</b>	<b>Problems</b>
Orbit Overlaps	GOCE Orbits	Position and Velocity Differences at Overlaps.	Internal Consistency Check
SLR Residuals	GOCE SLR Tracking Data	RMS and Mean of Laser Ranging Residuals.	Few SLR Tracking Data for GOCE expected.
External Orbit Comparisons	External GOCE Orbits	Position and Velocity Differences.	Quality of External Orbits not known.

# WP8000 Product Validation

## *Gravity Field Validation*

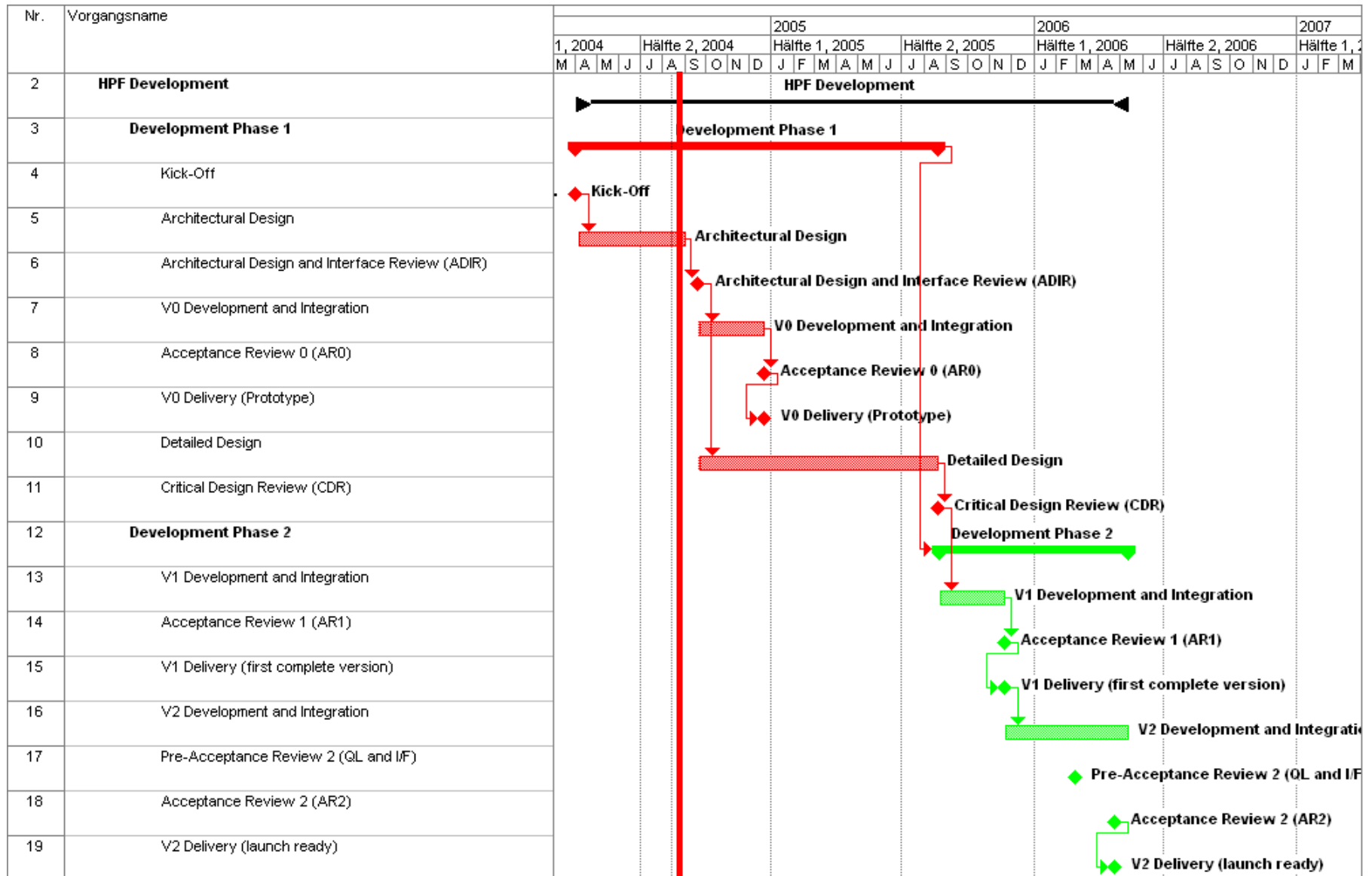
<b>Tool</b>	<b>Test Data Sets</b>	<b>Range of Test</b>	<b>Quality Parameters</b>	<b>Problems</b>
POD for other Geodetic and Altimeter Satellites	Tracking Data: SLR, DORIS, PRARE, GPS, Altimetry	Degree: 0-70 Resolution: 300-20000 km	Tracking Data Residuals; Altimeter Crossover Differences.	Tracking & Altimeter Data Quality; Satellite Sensitivity; Non-gravitational Disturbances.
Internal Error Assessment	Variance-Covariance Matrix	Full Spectrum of Solution	Error Degree Variances; Propagated Errors; Correlations;	Fully dependent on Error Calibration

# WP8000 Product Validation

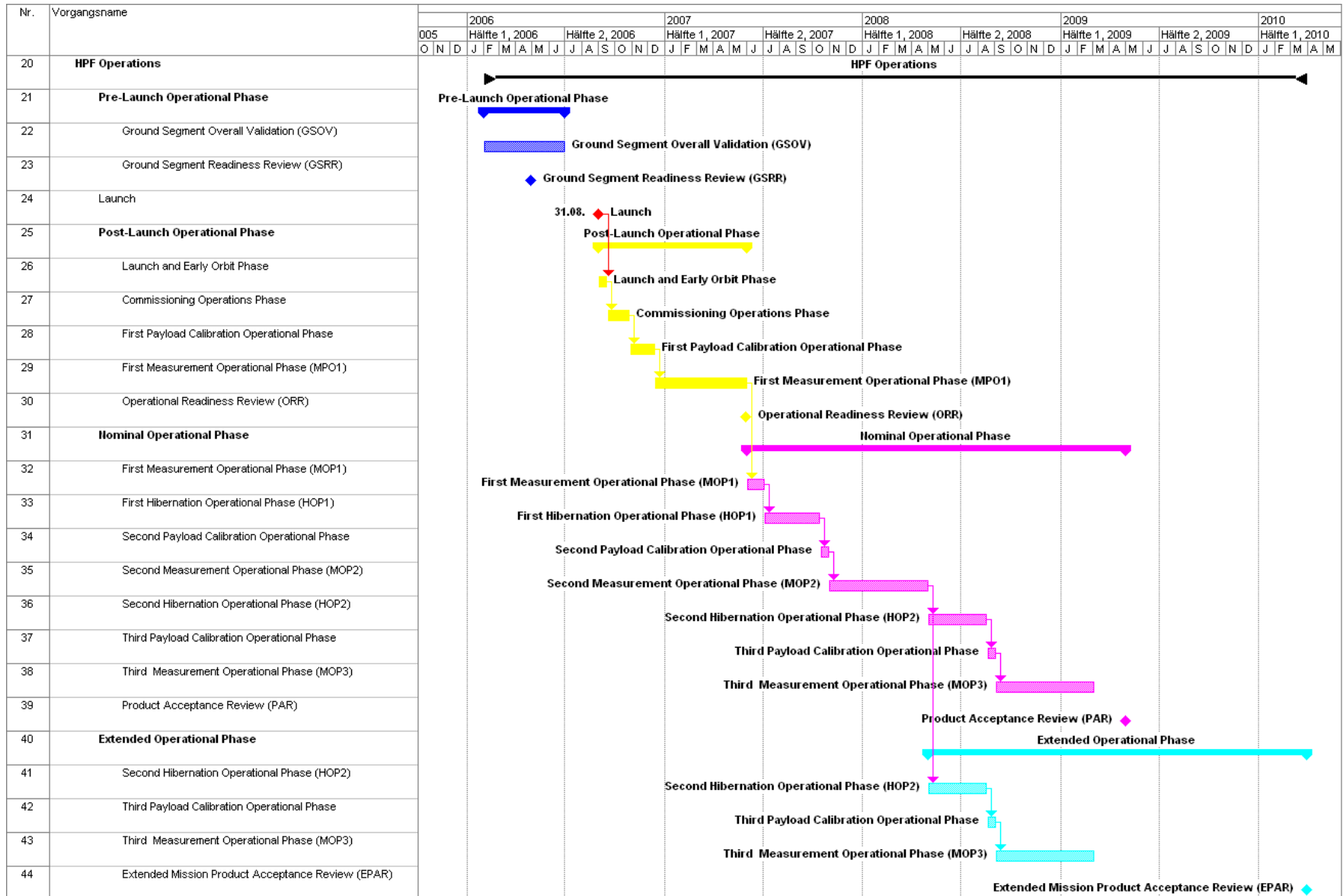
## *Gravity Field Validation*

<b>Tool</b>	<b>Test Data Sets</b>	<b>Range of Test</b>	<b>Quality Parameters</b>	<b>Problems</b>
Independent Geoid and Gravity Information	GPS- Levelling Geoid Heights; Gravity Anomalies	Degree: 50- 250 Resolution: 80-400 km	RMS and Mean of Differences at the Points of Comparison and Slopes.	Treatment of Omission Error; Filter Model; Impact of long Wavelengths.
Analysis of Sea Surface Topography Solutions	Mean Sea Surfaces from Altimetry; Oceanogr. Sea Surface Topography Solutions	Degree: 10- 250 Resolution: 80-2000 km	Differences between Geodetic and Oceanographic Solutions; Test for Remaining Oceanographic Signals.	Quality of Mean Sea Surface and Oceanographic Sea Surface Topography Models; Filtering; Ocean Boundaries.

# HPF Schedule - Development



# HPF Schedule - Operations



# HPF Level-2 Products

Identifier	Description
<b>Products of WP 3000</b>	
EGG_NOM_2	<ul style="list-style-type: none"><li>• Externally calibrated and corrected gravity gradients in GRF (2 weeks latency)</li><li>• Corrections to gravity gradients due to temporal gravity variations</li><li>• Flags for outliers, fill-in gravity gradients for data gaps with flags</li><li>• Statistical information</li></ul>
EGG_TRF_2	<ul style="list-style-type: none"><li>• Externally calibrated gravity gradients in Earth fixed reference frame including error estimates for transformed gradients</li><li>• Transformation parameters to Earth fixed reference frame</li></ul>
<b>Products of WP 8000</b>	
SST_PSO_2	<ul style="list-style-type: none"><li>• GOCE precise science orbits final product</li><li>• Quality report for precise orbits</li></ul>
EGM_GOC_2	<ul style="list-style-type: none"><li>• Final GOCE Earth gravity field model as spherical harmonic series including error estimates. Target: 1-2 cm / 1 mGal up to degree and order 200 corresponding to 100 km spatial resolution.</li><li>• Variance-covariance matrix of final GOCE Earth gravity field model</li><li>• Grids of geoid heights, gravity anomalies and geoid slopes computed from final GOCE Earth gravity field model including propagated error estimates</li><li>• Quality report for final GOCE gravity field model</li></ul>

# HPF Final Level-2 QL Products

Identifier	Description
<b>Products of WP 4000</b>	
SST_RSO_2	<ul style="list-style-type: none"><li>• Rapid science orbit from reduced dynamic approach</li><li>• Rapid science orbit from kinematic approach</li><li>• Rapid science orbit quality assessment</li></ul>
<b>Products of WP 6000</b>	
EGM_QLK_2	<ul style="list-style-type: none"><li>• Quick-look Earth gravity field model from SST only</li><li>• Quick-look Earth gravity field model from SGG only</li><li>• Quick-look Earth gravity field model from SST and SGG combination</li><li>• Diagnosis report sheets for all models</li></ul>
<b>Products of WP 8000</b>	
EGM_QLK_2	<ul style="list-style-type: none"><li>• Quick-look gravity field quality assessment report</li></ul>

**All products are delivered in XML format !**

# Conclusions

- **The HPF is developed by the European GOCE Gravity Consortium (EGG-C) under contract of ESA.**
- **Project has started in April 2004 and runs according to plan.**
- **The HPF will deliver orbit and gravity field products in different quality levels**
  - **QL products for validation purposes**
  - **Final products with highest level of accuracy as official GOCE ESA products**