Gaia

Overall Status, Accuracy, Data Analysis

RVS, Cambridge, 15 September 2005

Michael Perryman, ESA-ESTEC

Gaia

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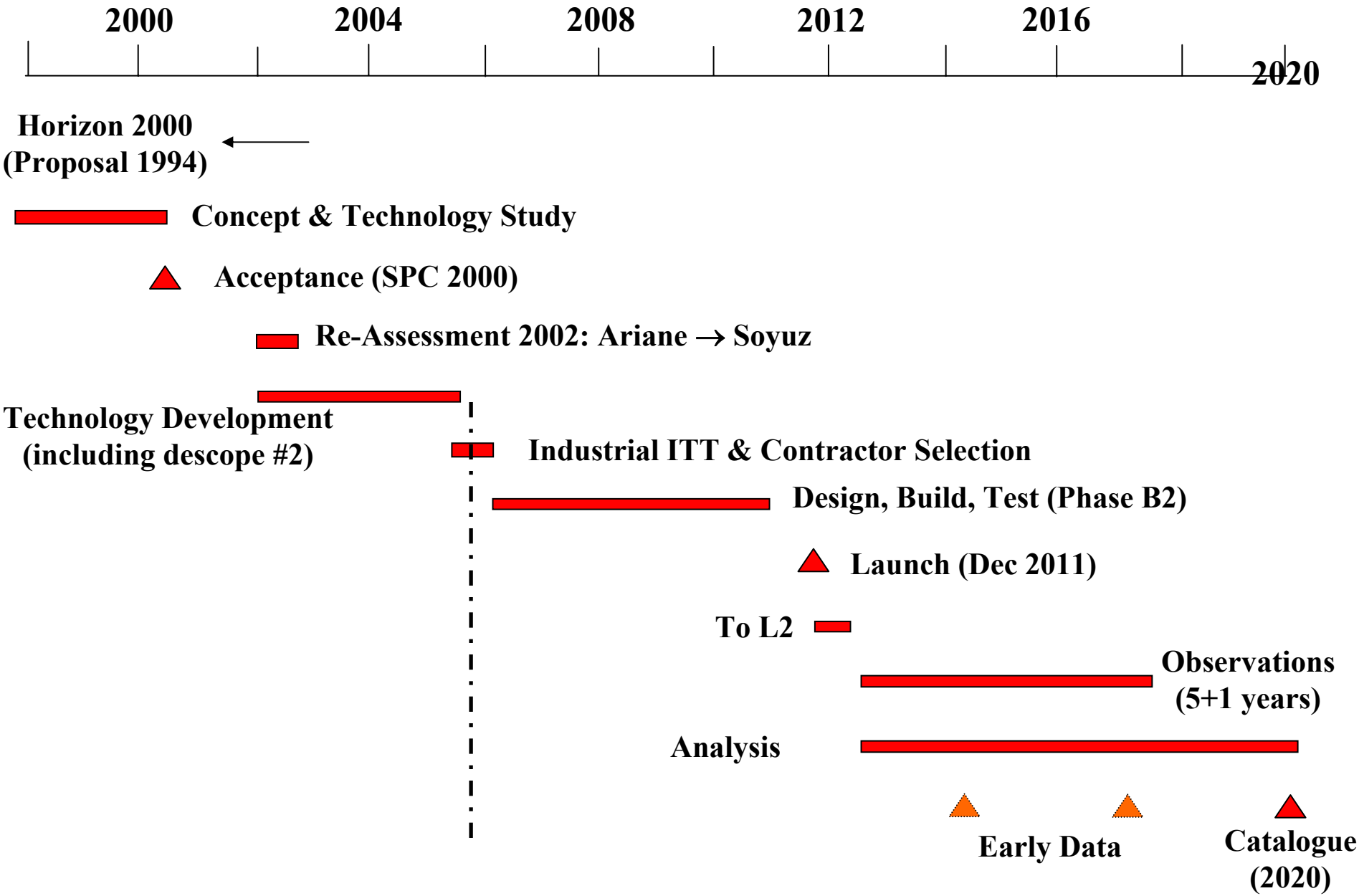
AWG, 22 September 2005

Michael Perryman, ESA-ESTEC

Schedule


2000
2004
2008
2012
2016
2020
Horizon 2000
(Proposal 1994)
Concept & Technology Study
Acceptance (SPC 2000)
Re-Assessment 2002: Ariane → Soyuz
Technology Development
(including descope #2)
Industrial ITT & Contractor Selection
Design, Build, Test (Phase B2)
Launch (Dec 2011)
To L2
Observations
(5+1 years)
Analysis
Early Data
Catalogue
(2020)

Status and Schedule

- Assigned to Project Team in mid-2004: Rudi Schmidt + 10
- B1 study phase completed in June 2005, with two competing industrial contractors (Astrium + Alenia/Alcatel)
- Release of industrial ITT for Phases B2/C/D: 30 June 2005
- Future schedule:
  - proposal deadline: 4 October 2005
  - major TEB review process will be completed by 23 December
  - AC and IPC decisions expected by the end of February 2006
  - start of Phase B2 immediately afterwards: March 2006
- No specific technical or schedule crises, but difficult areas include: radiation effects on CCDs, thrusters, data handling; thermal control; sun shield
- Current target launch date: 1 December 2011 (feasible)
  (compare with 2010-15 considered in 1995, 2010-12 by SPC in 2000)

Accuracy Development and Costs

- Accuracy is a complex issue: depends on astrometric parameter, magnitude, stellar type, reddening, instrument models, WFEs, radiation damage, margins, etc, etc
- Detailed accuracy tools in place in industry and ESA/science community
- Reference: parallax standard error at 15 mag for unreddened G2V star
- Evolution:
  - 2000: acceptance by SPC (Ariane 5, 580 M€): 10 microarcsec
  - 2002: SPC-level descope (Soyuz, 460 M € {→ 540 in 2005}): 15 microarcsec
  - 2004: transfer to project team (issues of mass, cost, schedule): 20 microarcsec
  - 2005: further cost reductions imposed (~520 M €): 20-25 microarcsec

  → Direct implications for luminosity and dynamical programmes, relativity, planetary systems, etc, etc (ironic given future planning for exoplanet and fundamental physics missions)
- Positive:
  - frozen in Mission Requirements Document, endorsed by Project
  - appear feasible; photometry and radial velocity targets largely met

Industrial Status and Satellite Design

- After issue of ITT (with Mission Requirements), 30 June 2005, contacts with industry ceases until proposal due on 4 October
- Requirements specified by ESA, design solution from industry
- Proposal content will remain confidential until selection and IPC (industrial Policy Committee) approval (Feb 2006)
- This phase is strictly competitive; current design plans are known to ESA project team + subset of Gaia Science Team
- Final design solution is not known outside of industrial teams
- Certain principles are known, e.g. CCD and astrometric FPA, leading to flight procurement programme for CCDs (e2v), itself indicating ESA's commitment to the 2011 launch schedule

Astrometric and Photometric Accuracy

Astrometry:

- Limiting (completeness): V~20 (actually G~20)
- ~1 billion stars (perhaps 1.3 billion)
- Formulated as 5-year parallax, all sky average
- Accuracies constant with G magnitude, but formulated for unreddened B1V, G2V, M6V:
  - V=10: 7, 7, 7 microarcsec (1 milliarcsec for Hipparcos)
  - V=15: 25, 24, 12 microarcsec (original target: 10)
  - V=20: 300, 300, 100 microarcsec

Photometry:

- Multi-colour (~14 bands), multi-epoch photometry to 20 mag, with accuracies functions of band and spectral type

Radial Velocity Accuracy

- Requirements:
  - Completeness at V=13.0, 17.5, 18.5 (B1V, G2V, K1III metal poor)
  - 15 km/s accuracy at V=12.0, 16.5, 17.0
- Goals: fainter than requirements by 0.5 mag
- Radial velocity completeness, at some accuracy, to 20 mag is the ideal, but not-achievable with dispersed light and constraints on mirror size, mass, accommodation, cost
- Requirements can be met with reference CCD technology, given the technology development completed pre-ITT
- Goals can be met with L3CCD technology, but with additional cost, and additional technical and schedule risk
- Project team is opposed to this risk, given cost and launch date
- Options for L3CCD technology should be given by industry, and subsequently evaluated by ESA
- Development studies are ongoing within e2v, MSSL, Brunel

Data Processing and Analysis Consortium: Status and DACC

Science Operations, Data Processing

- Science Management Plan in preparation (SPC, end 2006)
- Spacecraft operations at ESOC (under project team):
  - Fixed scanning law
  - Fixed instrumental configuration in survey mode
  - No observing/instrument planning or scheduling
  - Payload health monitoring will take results from scientific analysis
- Two elements under Project Scientist responsibility:
  - Accuracy, system and project team support, interface with scientific community (e.g. www.rssd.esa.int/Gaia)
  - ESAC contribution to the Gaia data processing:
    - of order 1 Petabyte of data to be stored and managed (huge)
    - of order 10**21 FLOPS of numerical computation (very huge)
    - algorithmic complexity
- After 3 years of development (UB/GMV) the GDAAS prototype still cannot yield convergence for 1 million stars, 18 months mission
- Problem is too big for the community alone, too complex for ESA alone

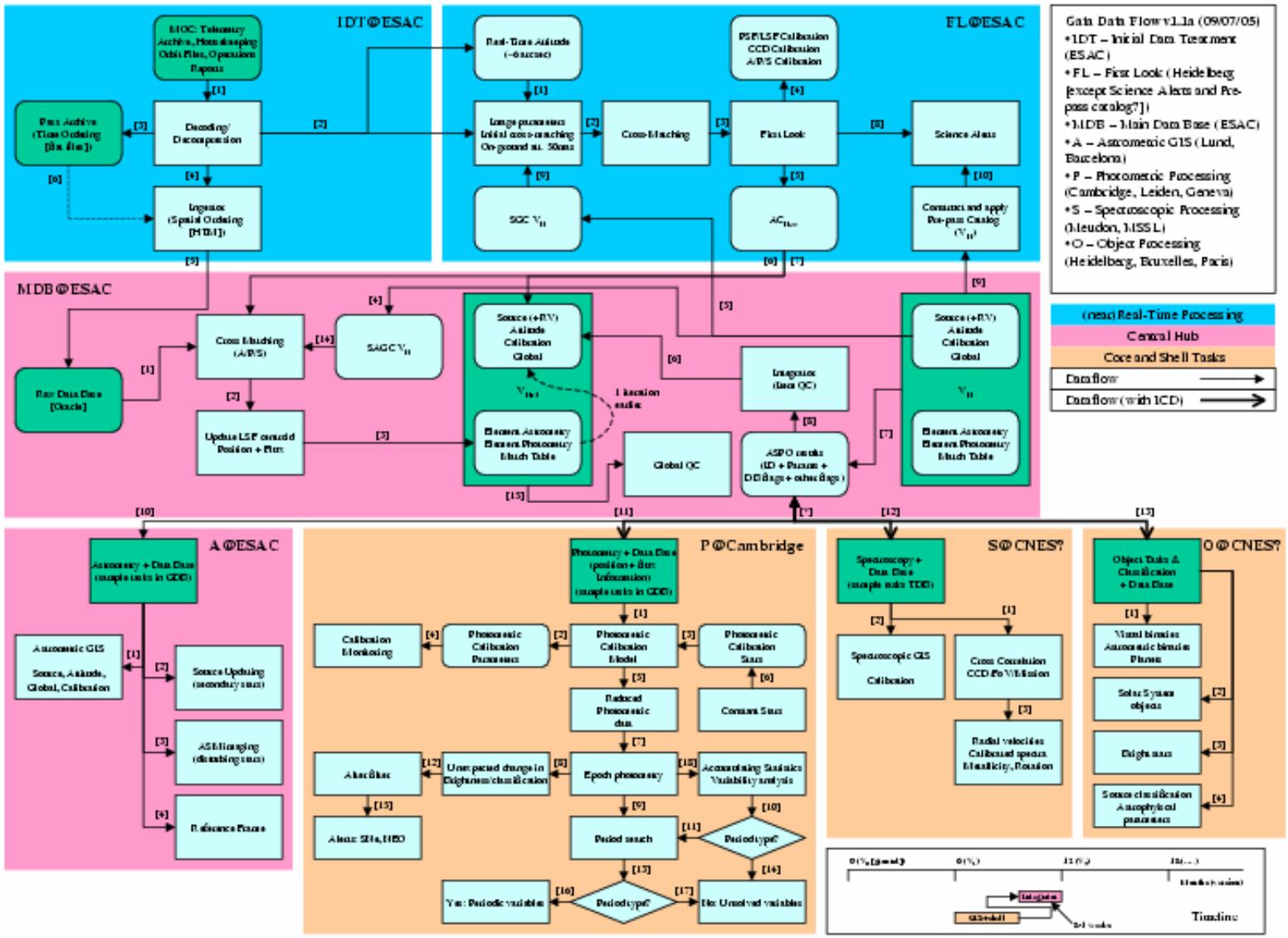
Gaia Data Processing & Analysis Consortium

- Ingredients:
  - Knowledge and expertise from Hipparcos
  - Results from the GDAAS iterative solution prototype
  - Scientific studies of 16 working groups: 2000-2005
  - Deliberations, studies, and consultations by Science Team
  - Inputs from the (early 2005) Letters of Intent exercise (177)
- Establishing the DPAC has been assigned to an interim Data Analysis Consortium Committee (DACC):
  - Chairs: F. Mignard (Nice), Coryn Bailer-Jones (Heidelberg) + 8 involved members of the Gaia community + Project Scientist + 2 ESAC
  - Reports to the Gaia Science Team
  - Aims to have a structure in place by around March 2006
  - DACC will be dissolved, and replaced by a Data Analysis Executive Committee comprising leaders of the eventual Data Processing Consortium
  - The DPAC should be in place to coincide with the start of Phase B2
  - The structure will be formalised by an ESA AO (around mid-2006?)

Data Processing: Coordination Units (CU)

- Aiming for a single, simple, logical structure, with self-contained coordination units:
  - CU1: overall system architecture, data base
  - CU2: scientific data simulations
  - CU3: core processing (astrometric global iterative solutions)
  - CU4: object processing: shell tasks and classification
  - CU5: photometric data processing
  - CU6: spectroscopic data processing
  - CU7: catalogue access and exploration (activated later)
- CUs will have leaders, formal structure and responsibilities:
  - sub-divided into Development Units and Work Packages
  - unified interfaces, programming guidelines, language, libraries, etc, as specified by CU1
  - algorithms delivered, integrated, tested, executed within 5-6 centres

Data Processing: Overall Data Flow



Major Processing Centres*: Current Intentions

- ESAC (leading CU1, contributing to CU3):
  - data reception, storage, global iterative solution, integration of results from other processing centres, iterations of main + results data base
  - execution via dedicated hardware at ESAC (possibly GRID)
  - 10 FTE + hardware contribution foreseen in ESA's mission CaC
  - 50(→100) GFLOP machine in place in an initiative with Dell
  - significant contribution to processing hardware indicated from Spain
- University of Barcelona (CU3): Mare Nostrum
- CNES Toulouse (CU4): object analysis (shell tasks, classification)
- University of Cambridge (CU5): photometric data processing
- University of Geneva/ISDC (CU5): variability analysis
- CNES Toulouse (CU6): spectroscopic data analysis

*Note: execution only – significant additional algorithmic development is ongoing/planned within community (Lund, Heidelberg, Paris-Meudon, Torino, Dresden, Leicester, Leiden, Bruxelles, etc)

Summary

- Gaia should enter implementation phase in March 2006
  - Because of technical development programme, Gaia should enter Phase B2 with relatively limited technical risk
  - 2011-2012 launch schedule is realistic, unless funding cuts
  - Project team is committed, industrial designs are sound
  - Some negotiations may be needed with the radial velocity CCDs
  - No further astrometric accuracy degradation should be admitted
- Effort is now ongoing to establish a coherent structure for a single Gaia data processing consortium:
  - ESA contribution is now in place
  - Consortium should be in place by mid-2006
  - AO will be needed to formalise national commitments
  - Some countries may have to push hard for their planned contributions
  - The data processing is a vast numerical, algorithmic, and sociological challenge: we do not intend to be side-tracked by political complexities