Taking up the Gaia Challenge: DPAC Operations

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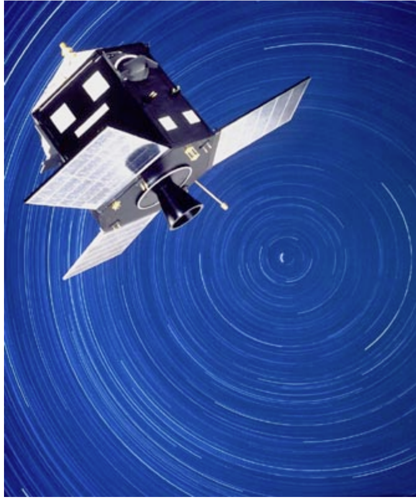
Outline

- Summary of the Gaia mission and goals
- The Gaia satellite and it scientific instrumentation
- The Gaia science ground segment: layout and operations
- Lessons learned from the development phase

Gaia's predecessor



Hipparcos:

position accuracies of 1 milli arcsec

for 118.218 stars down to V~12.4^{mag}

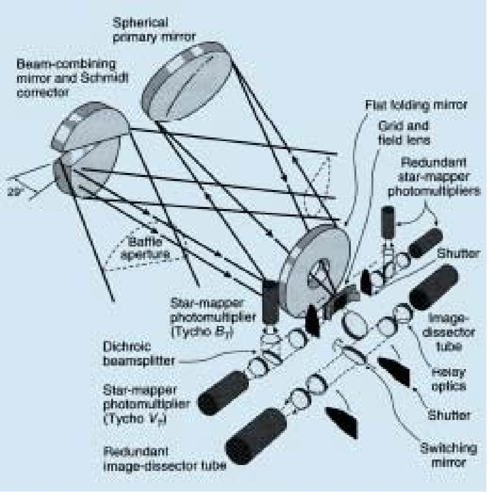
+ photometry

see M. Perryman (1997) and F. v. Leeuwen (2007)

Measurement principle:

A 29cm telescope, observed simultaneously two FOVs separated by a 'basic angle' of 58º.

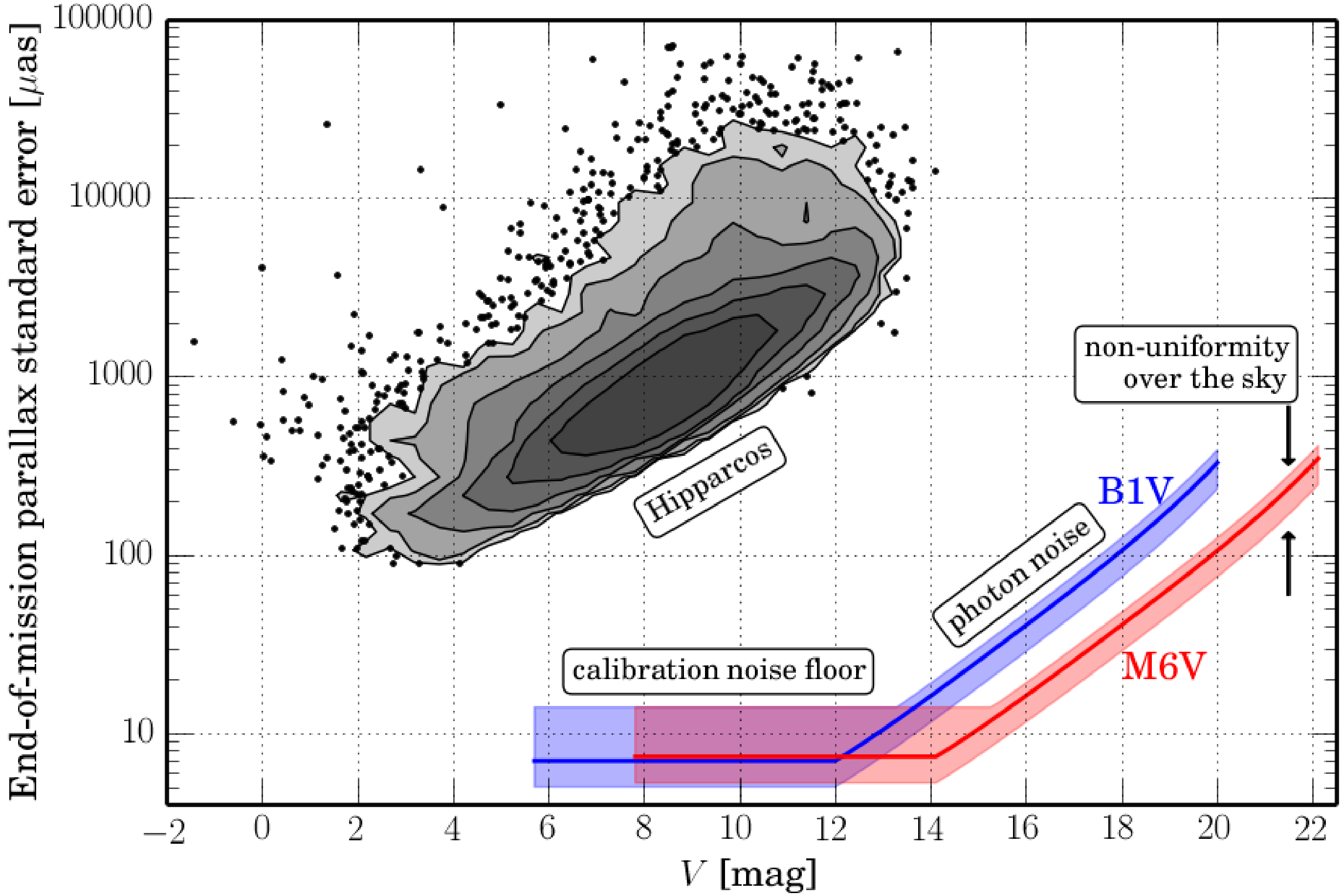
Rotation of the apparatus allowed to measure the timing of the transiting stars in both FOVs.



The leap: Gaia's mission goals - I -

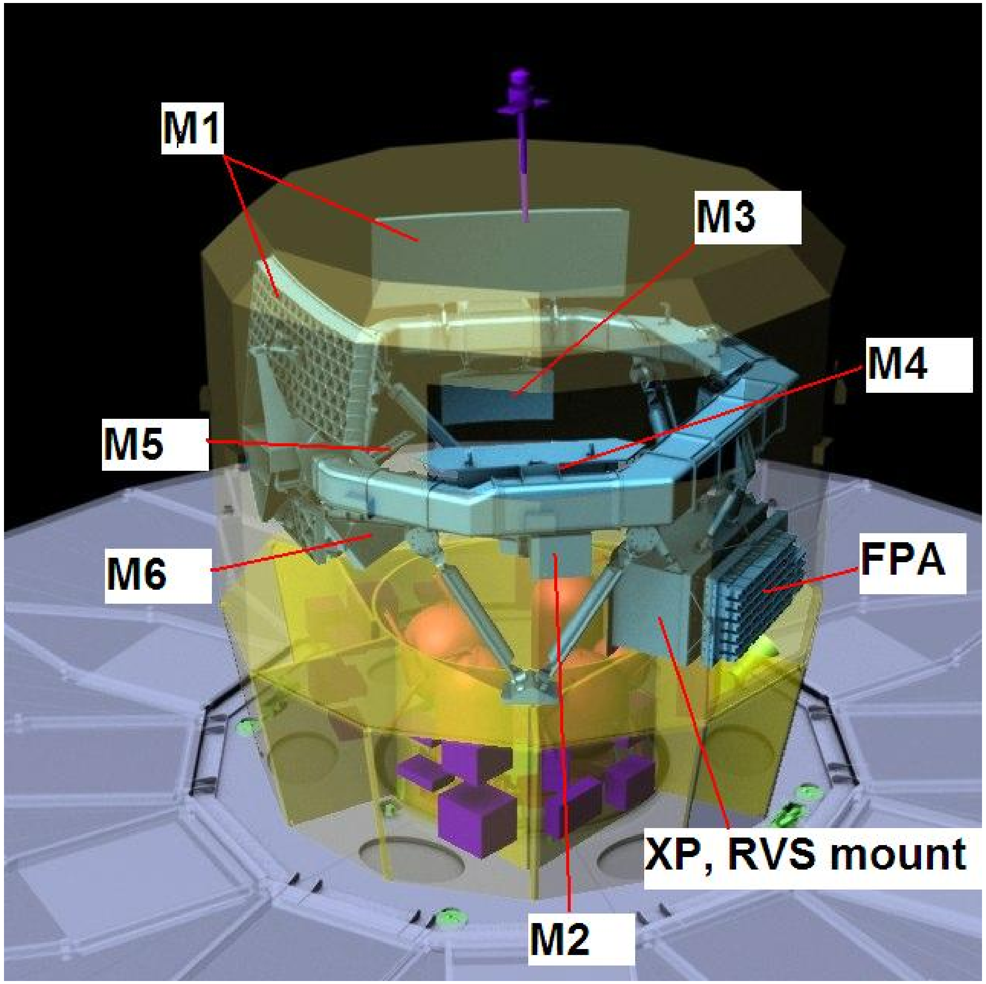
	Hipparcos	Gaia
Magnitude limit	12	20 mag
Completeness	7.3 – 9.0	20 mag
Bright limit	0	6 mag
Number of objects	120 000	26 million to V = 15
		250 million to V = 18
		1000 million to V = 20
Effective distance	1 kpc	1 Mpc
Quasars	None	5×10^5
Galaxies	None	$10^6 – 10^7$
Accuracy	1 milliarcsec	7 µarcsec at V = 10
		10-25 µarcsec at V = 15
		300 µarcsec at V = 20
Photometry	2-colour (B and V)	Low-res. spectra to V = 20
Radial velocity	None	15 km/s to V = 16-17
Observing	Pre-selected	Complete and unbiased

The leap: Gaia's mission goals - II -

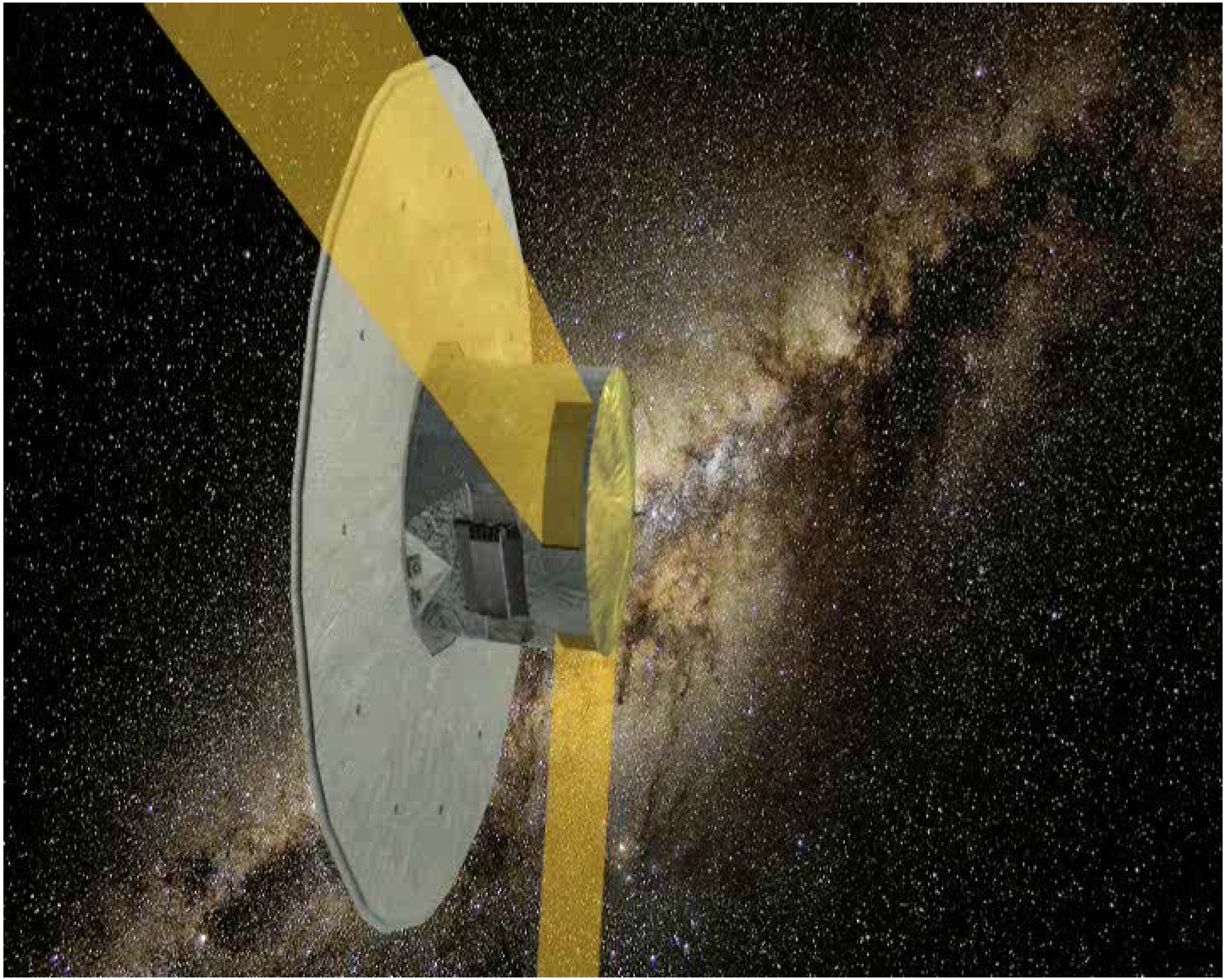


Gaia's optical layout and instrumentation

- 2 telescopes with 1.4m x 0.5m aperture each, f=35m
- Total of 10 mirrors comprising folding mirrors and beam combiner
- A single focal plane on which both FOVs are projected
- Further instrumentation:
  - Photometer prisms
  - RV spectrometer
  - Basic angle monitor
  - Wavefront sensor (commissioning only)
- The entire space craft was designed and built by European industry (no "instrument teams")

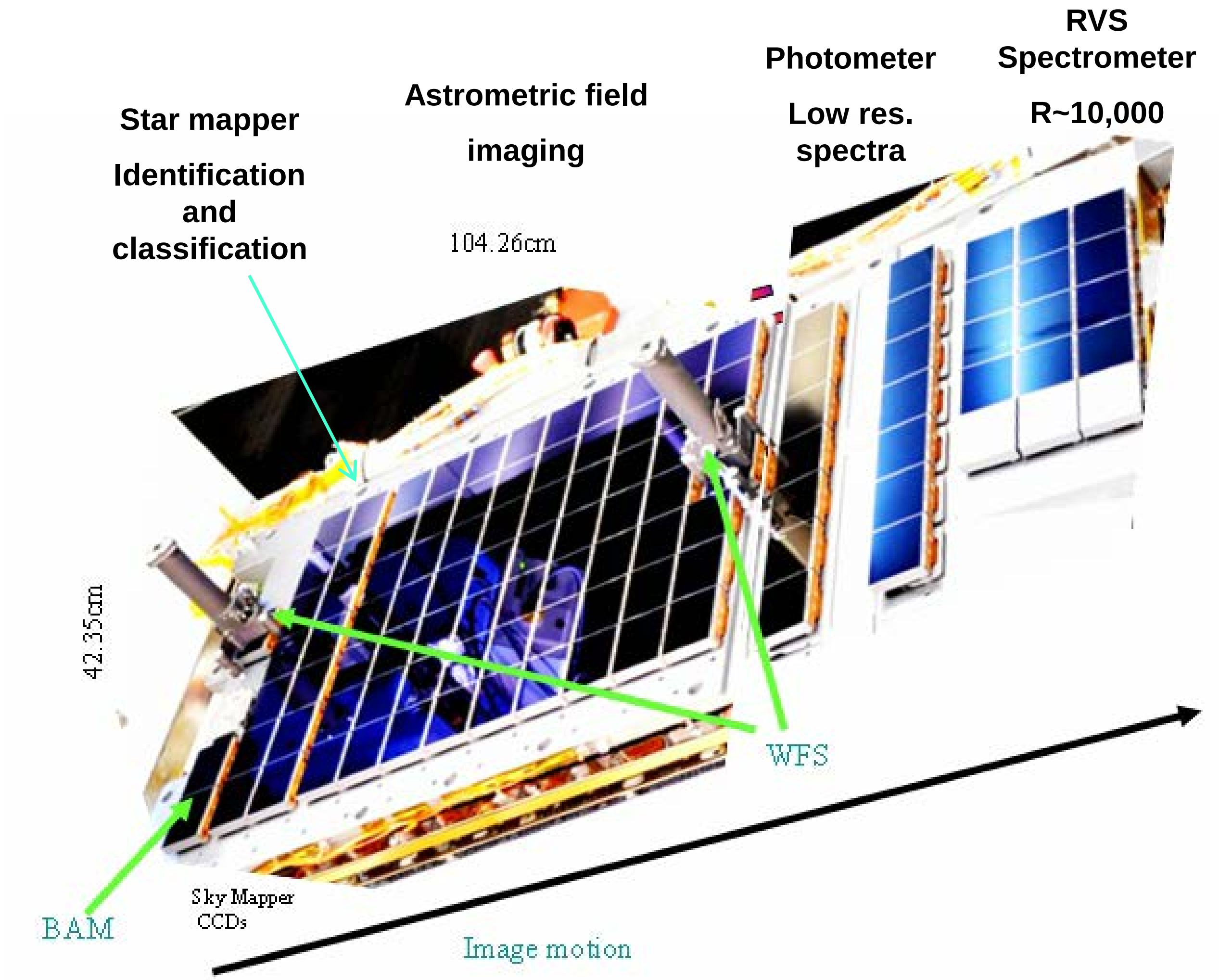


Gaia will scan the sky from L2



Gaia's focal plane

106 CCDs, each 4500px AL x 1966 AC, read in TDI mode



DPAC organization and tasks

- Gaia Data Processing and Analysis Consortium (DPAC) is the scientific consortium which will
  - Conduct the processing of the Gaia data
  - Perform the scientific analysis of the Gaia data
  - Compile the Gaia catalogue which will deliver the Gaia promise to the scientific community
- DPAC is structured in
  - Coordination Units (CU) whose members are scientists and engineers developing the analysis methods, algorithms and software
  - Data Processing Centres (DPC) which operate the hardware to process the Gaia data, using the CU provided software products
- Overall, DPAC has more than 450 members, mostly in Europe and some also worldwide

The DPAC CUs and DPCs

- DPCB University of Barcelona
  - CU2: Simulations and CU3: Core processing
- DPCE ESAC and DPCB University of Barcelona:
  - CU3: Core processing
- DPCT Altec Torino:
  - CU3: Astrometric verification unit
- DPCC: CNES Toulouse
  - CU2: Simulations
  - CU4: Non-single stars, solar system objects, extended objects
  - CU6: Spectroscopic processing
  - CU8: Astrophysical parameters
- DPCI: Institute of Astronomy at Cambridge
  - CU5: Photometric processing
- DPCG: ISDC/Geneva University
  - CU7: Variability

Gaia's main science operations groups

- Gaia is a survey mission, thus there should not be too much interaction with the user
  - Mission operations centre (ESOC): S/C control
  - SOC/DPCE (ESAC): S/C science control, central DPAC hub
  - DPCs: DPAC data processing centres
  - Payload Experts:
    - DPAC (CU) experts covering all scientific and instrumental aspects
    - Conduct performance assessment and verification
    - Support spacecraft configuration decisions during the mission
  - DPAC Executive: board of directors
  - Gaia Science Team: science advisory group to PS and MM

DPAC's "daily" operations branch -I-

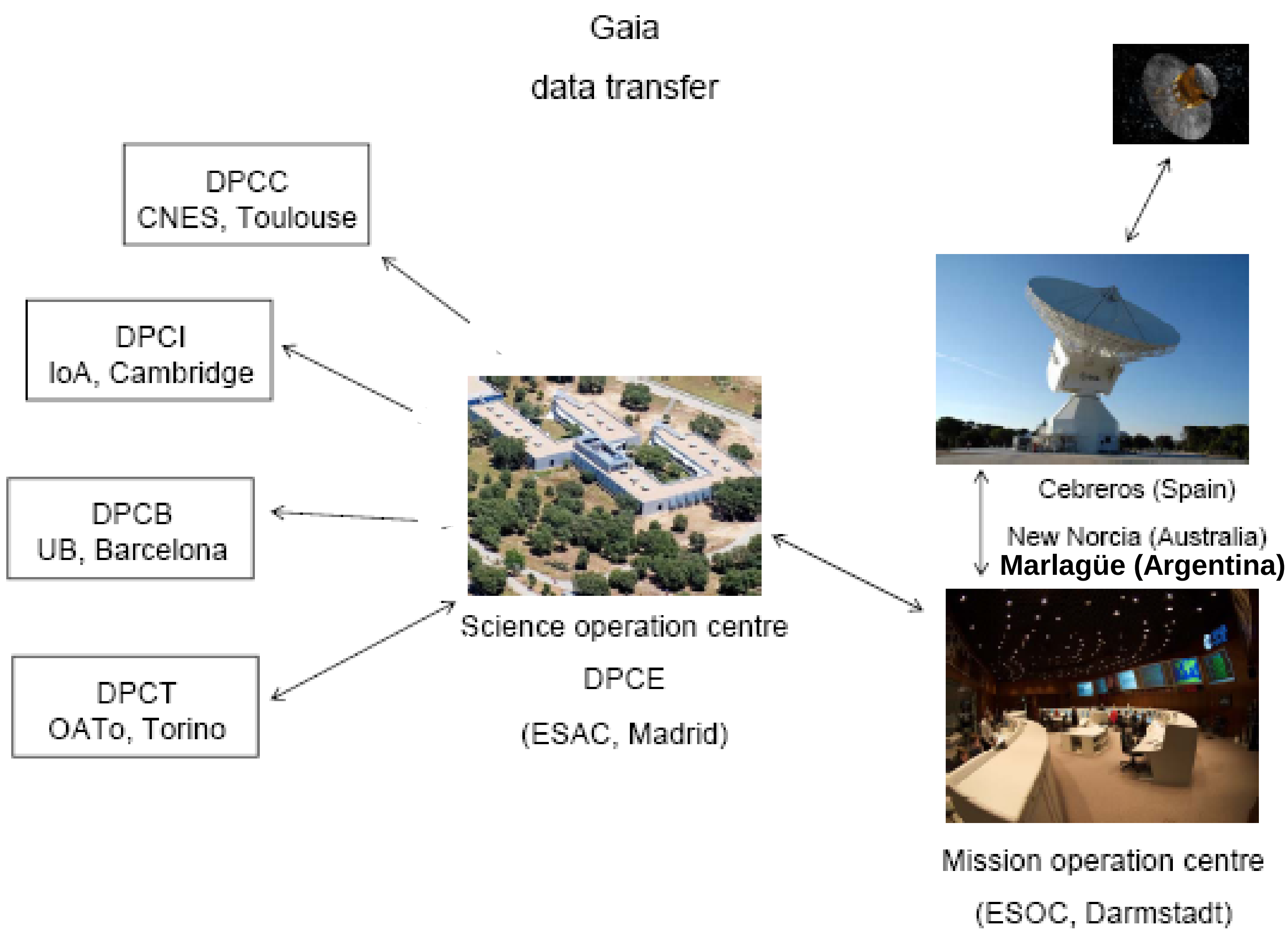
- Goals:
  - Scientific performance + health monitoring of Gaia
  - Obtaining short term instrument calibrations
    - Trigger setup changes on-board, if necessary to improve science performance
  - Detection of certain transient phenomena

- How:
  - Data are processed asap after reception on-ground
  - Most of this processing works on data covering only few (~1-20) days

DPAC's "daily" operations branch -II-

- Who:
  - DPCE/SOC:
    - First Look (CU3, SCIs): ODCs, AF, BP/RB, RVS, BAM
    - GBOT (CU3) interface
  - DPCC:
    - RVS monitoring (CU6)
    - Solar System Object Short Term (CU4)
    - SSO alerts (CU4) <-> IMCCE
  - DPCI:
    - BP/RP processing and calibration (CU5)
    - Science alerts interface (CU5)
  - DPCT:
    - BAM+AIM monitoring (CU3-AVU)

Daily data transfers during the Gaia mission



DPAC's cyclic operations branch -I-

Goals

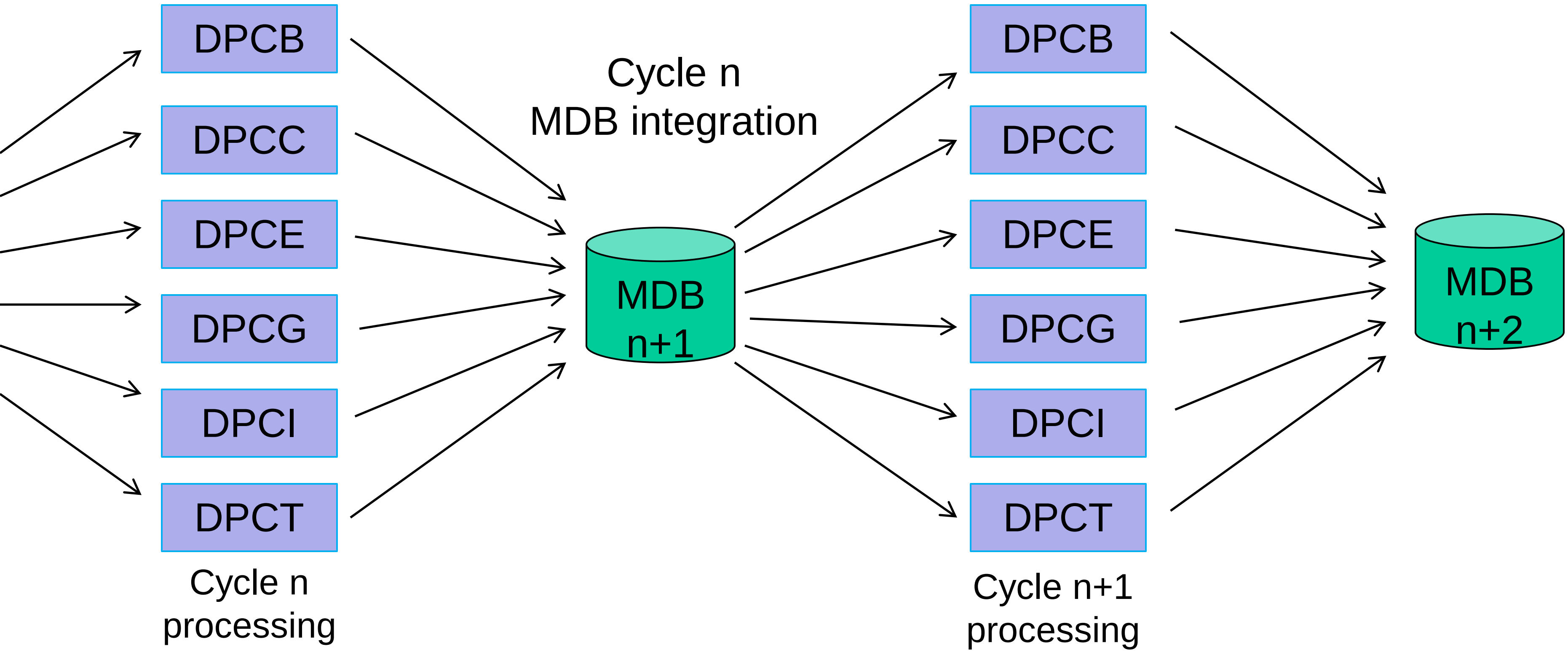
- Produce high fidelity calibrations
- Generate science data products, ultimately for catalogue releases

How

- All data collected since the begin of the mission are processed at certain intervals: the data reduction cycles (DRC)
- Highly iterative process (iterations are the DRCs)
  - MDB is the central data base
  - MDB is maintained at DPCE/SOC
- Cycle lengths range from few months up to 1 yr

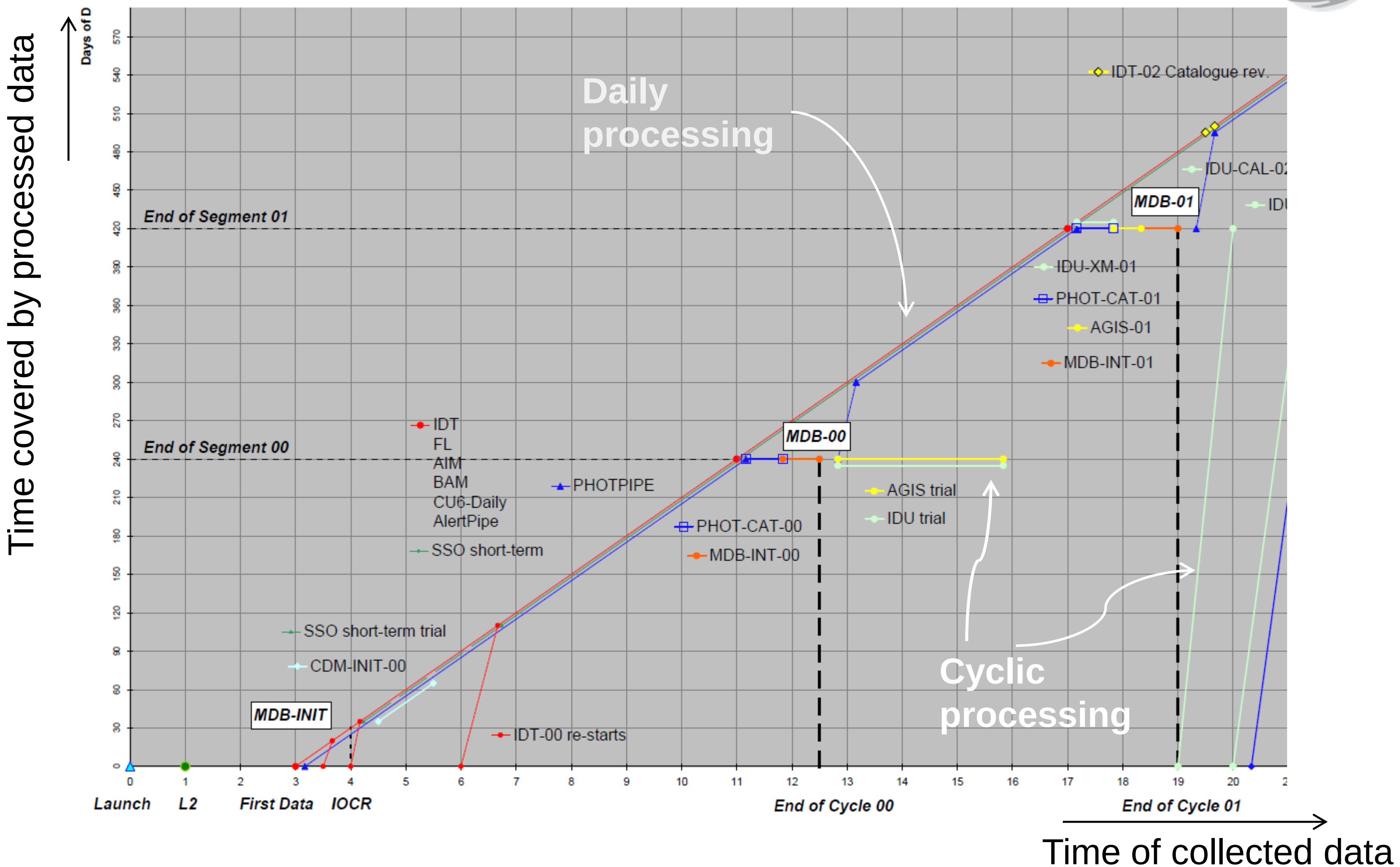
DPAC's cyclic operations branch -II-

Conceptual data flow from one cycle to the next



This process is complex, and the involvement of the individual DPCs depends on the data processing progress and availability of data.

A view of the data processing progress



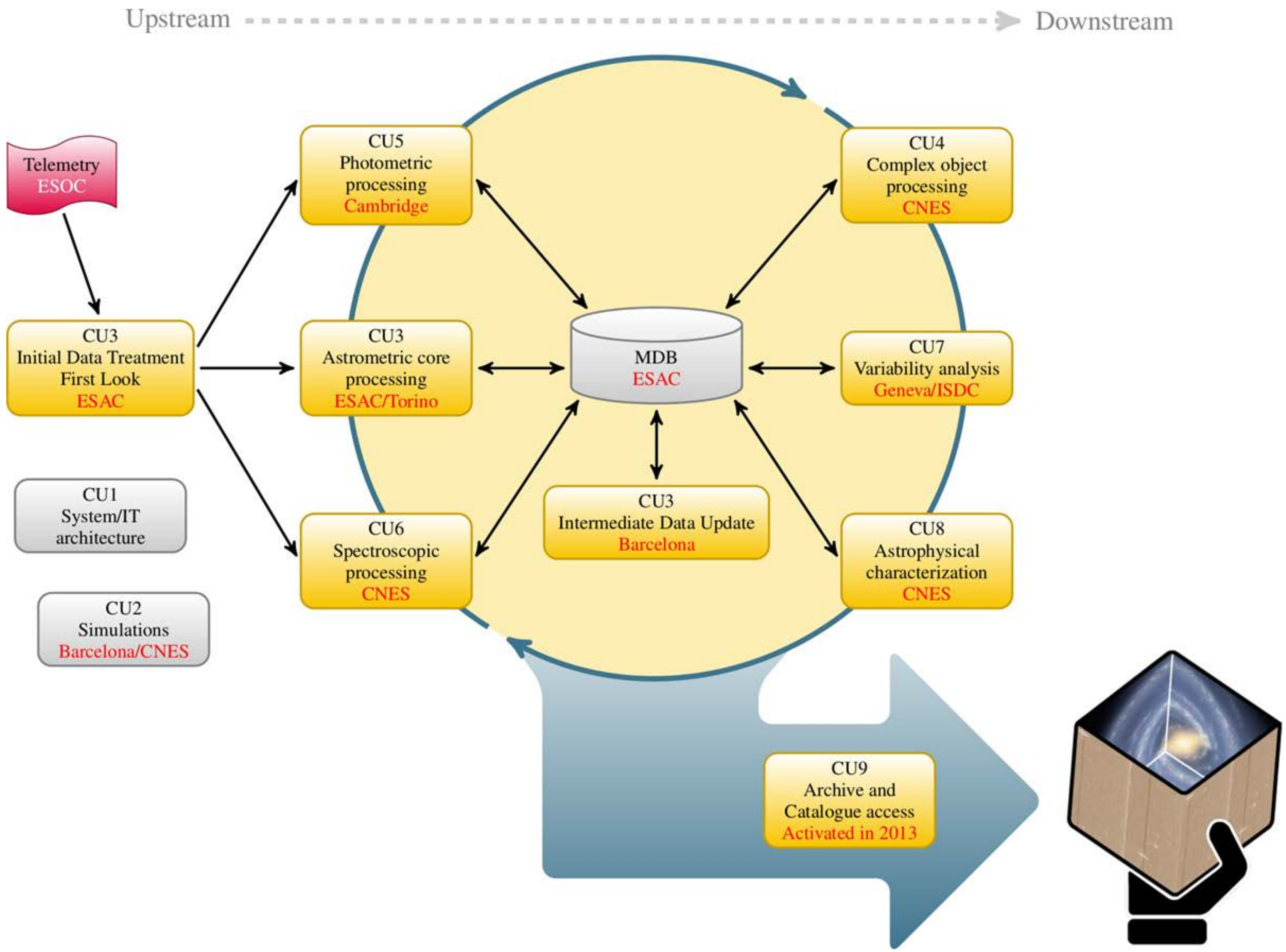
DPAC operations are catalogue release driven

- The Gaia catalogue intermediate catalogue release scenario, note that this is a best case scenario (full details can be found on

  http://www.rssd.esa.int/index.php?project=GAIA&page=Data_Releases)

  - L+22 mo: positions and G magnitudes for single stars
  - L+28 mo: five parameter astrometric solution for single stars, integrated BP/RP photometry, sources with verified astrophys. parameters, RVs which show no variability.
  - L+40 mo: orbital solutions, system RV, five parameter astrom. solution for binaries, object classification and astrophys. parameters, BP/RP spectra, and/or RVS spectra and mean RV for non variables and for which atmosph. parameters are available.
  - L+65 mo: variable star classification and epoch photometry; preliminary SSO orbital solutions, and epoch observations; non-single stars catalog
  - EOM+36mo: Final catalog release

DPAC operations in a single picture



Lessons learned from the DPAC development, impacting operations -I-

- Availability of simulations is crucial
  - DPAC knew that and CU2 did an excellent job in providing data
  - But: scope the simulation development and data generation carefully
    - There is not too much point in simulating all detection effects in all physical detail, if there are not yet the means to get the most basic sources/effects processed. Make sure that the upstream processes get realistic data first !
    - Having an almost perfect universe model is good, but take care that the development effort to simulate a particular class of objects, of which there are maybe only 10000, does not affect the operationally relevant simulations (previous bullet)
    - Having a system engineering overview of the project is crucial to scope the simulations (which might result in scientifically ‘boring’ simulations).

Lessons learned from the DPAC development, impacting operations -II-

- It is good to have close link between the simulations development team and the team developing the most upstream software
  - DPAC had those links (either planned or by coincidence) and they turned out to be useful
  - However: make sure that you separate both from a certain point onwards
    - It is within human nature to aim for passing tests
    - Having too close ties between the most upstream sw and simulations developments will result in mostly passed tests, which will ultimately be misleading
    - For operational tests, that link must be broken: yes, it’s painful but unavoidable

Lessons learned from the DPAC development, impacting operations -III-

- Testing, testing, testing – and then there is “integration testing”
  - DPAC follows the ECSS guidelines and testing is built into its development
    - Several years long and several stage E2E has, and still is, being conducted
    - Very difficult and time consuming as you go from the daily into the cyclic processing branch: this requires lots of data
  - But only the testing of the integrated system will allow to assess the status of the system
    - Start integration at the DPCs early, best more than one year earlier than you initially think
    - Integration of sw by various teams at a DPC can not be done by email exchanges only (communicate, communicate, communicate…)

Lessons learned from the DPAC development, impacting operations -IV-

- Conduct “simulation of operations” campaigns in addition to the regular testing campaigns
  - DPAC started to conduct “rehearsal” campaigns in mid-2012 and by now 4 of those have been conducted
  - Those are not only about processing (testing) – they must also cover/assess decision hierarchies, communication lines, system engineering, and they must raise operational awareness of the teams
  - But keep the goals and conduct within reason.
    - By making the first few of such exercises (you should have many!) too aggressive you might mislead people in their view on operations.

- There are many more lessons we have learned

Conclusions:
DPAC is preparing itself for November 20, 2013
Stay tuned for the first Gaia results

Loading at
Astrium Toulouse

Arrival at Kourou

Soon: off to L2…

Images courtesy: ESA and Astrium