

# Building the Gaia ground segment

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Or  
the good  
the bad  
and  
the ugly.

The western is quintessentially American, that one was Italian though and it was shot in Spain.

## 1 Initial Set up

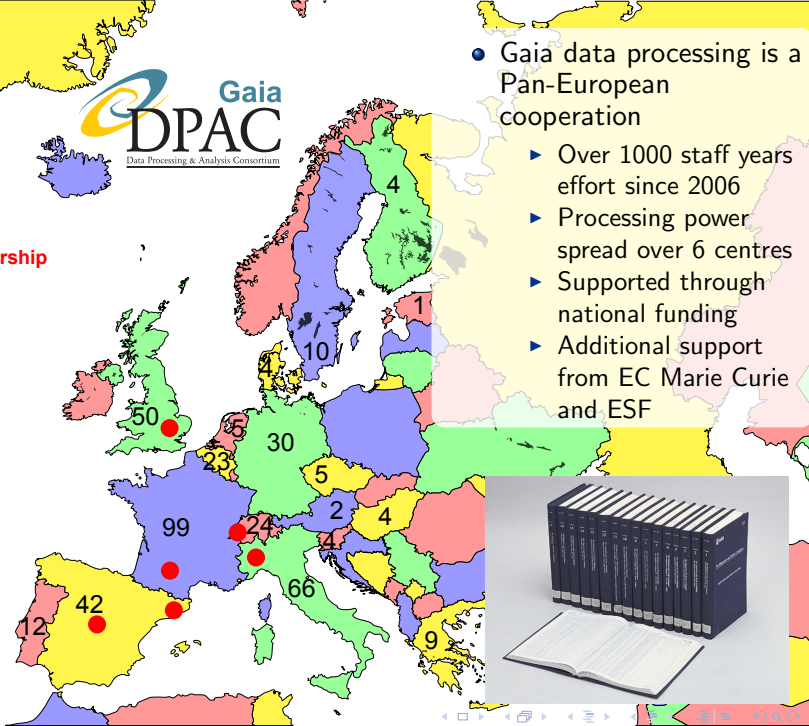
## 2 Standards and Tools

## 3 Management

## 4 Conclusion

**DPAC membership**  
**January 2013**  
**432 total**

BR: 5  
CA: 1  
CL: 1  
ESA: 28  
IL: 1  
US: 2



- Gaia data processing is a Pan-European cooperation

- ▶ Over 1000 staff years effort since 2006
- ▶ Processing power spread over 6 centres
- ▶ Supported through national funding
- ▶ Additional support from EC Marie Curie and ESF



## In the beginning

- initial ideas for ground segment were in place for the study in 2000 ESA-SCI(2000)4
- already clear then we would have distributed processing in multiple centres (though not mentioned)
- Intention was to have autonomy between coordination units
- Interviewed several project leaders for O'Mullane (WOM-003) in 2004/5 — tried to learn from them ...
  - ▶ Included LSST (Kantor)
  - ▶ Management came out as the most difficult part of all projects ... so I will leave that until last.
- some things started before DPAC — simulations and GIS studies for example.
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- Very important in large groups
- Which way is up on Gaia, which is a row and column on focal plane, which quaternion to use
- **dealt with quite early on in BAS-003**
  - ▶ still Astrium have a different definition for  $X$ ,  $Y$ ,  $Z$  on Gaia
  - ▶ at least in the consortium there is only one — could have been much worse
- What is a product, a Work Package — why is 10 months = 1 year
- also dealt with early on in WOM-001
- Then there are Acronyms  
<http://gaia.esac.esa.int/gpdb/glossary.txt> and an acronym tool for TeX files (e.g. Appendix 5)
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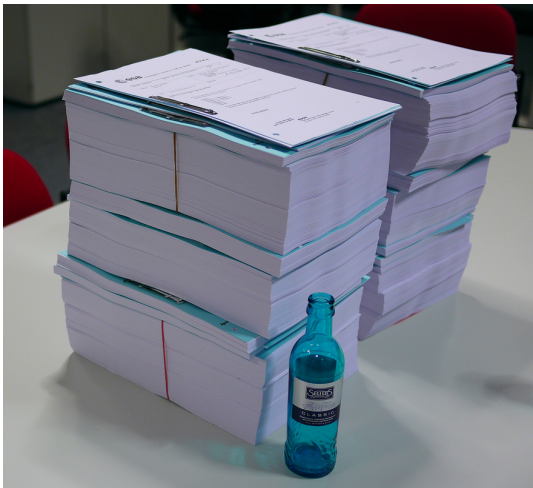
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- Avoid different values of constants in peoples code . . .
- The Gaia Parameter Database was set up early on for this (de Bruijne et al., 2005)
  - ▶ all constants in one place; web searchable configuration controlled (Only updated by Jos De Bruijne)
  - ▶ published as constants for Java (can also do C, Fortran. . . ) so you may refer to a particular version
- then the actual data model — what exactly is an AstroElementary?
  - ▶ entire data model defined in multi-user dictionary tool; includes Units on each field.
    - ★ good for astronomers — computer people find it harder to handle
  - ▶ from it we generate data instance classes and schemas for storage.
  - ▶ **ONLY data model not processing** — all objects are dumb
- **These are logical extensions of having agreed conventions. . .**

# Flight Operations Procedures in MOC

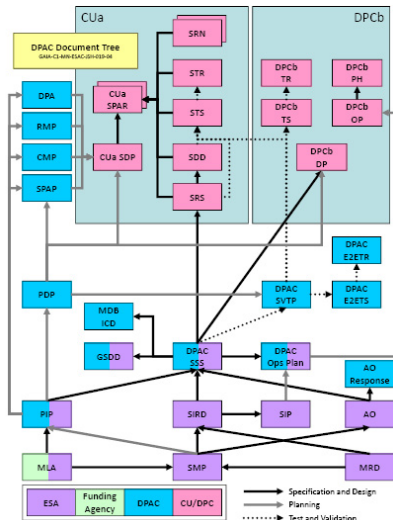


The FOP is followed by the spacecraft operators - the paper copy is just in case the computers fail. We should try to keep documentation useful.

# Have a standard: DPAC follows ECSS

## European Cooperation for Space Standardization

- ECSS tailored as in figure
  - ▶ LaTeX Templates/examples provided (by SOC)
  - ▶ Documents are iterated — All of this is done for all DPAC products.
  - ▶ It is very good to have a standard set of documents augmented by technical notes and streamlined ECSS
  - ▶ Some still found it too heavy — other reports requested beyond the standard ones.
- DPAC had sufficient QA people (~ 1/CU) from the start to help with this



Doctree by John Hoar (RD-010)

# Software licensing

- protect intellectual property — grant use to the consortium
- often forgotten or not well dealt with - or worse ignored!
- DPAC in general agree to LGPL (WOM-019) - some institutes e.g. ESA, do not allow staff to write GPL code.
- Being allowed LGPL in ESA for Gaia involved lawyers and directors and some of my time and some Herschel people.
  - ▶ now ALL ESA science missions can use LGPL with D/SRE approval.



## Single Sign on Gaia Portal

- <http://www.rssd.esa.int/index.php?project=MYPORTAL&page=index> hosted at ESTEC; set up eons ago...
- Names, emails and affiliations (phone numbers, photo, address) of all Gaia people
- Single login (LDAP) for
  - ▶ Livelink — for all published documents
  - ▶ Wiki — for wiki things (meeting setup etc.); always draft nearly always out of date
  - ▶ Mantis — for all issues
- Same LDAP for SVN, MDB dictionary etc
- Single sign on is perhaps not great but having one LDAP for authentication of everything is fabulous!
- Having information in SVN, Livelink and possibly on a wiki is not great but we do not have a solution
- Having single agreed set of collaboration tools from the outset excellent.



## Development tools

- All DPAC code and docs in Subversion, hosted at ESAC
  - ▶ Access control according to Group membership in the LDAP
- Mantis for centralized issue tracking (includes risks and actions)
  - ▶ ALL DPAC issues in one system hosted at ESTEC
  - ▶ **Jira would probably be better**
- **Having one language is good (2011)** agreed 2006 (JH-001) — only one verification part is NOT in Java.
  - ▶ Can have a library of standard routines GaiaTools (Relativity, Field Angle Calculator, Ephemeris handling. . . )
    - ★ The set of routines were not defined hence GaiaTools is a bit of hodgepodge mess. . .
    - ★ Counter argument for common tools is (unnecessary) interdependence. . .
  - ▶ all libs in Nexus
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- Internal

- ▶ the newsletter is excellent and well contributed to
- ▶ (few) focused working groups and working meetings
- ▶ To date never had a consortium meeting; **probably a mistake.** — we do intend this during processing
- ▶ As for any project cost of entry for new people is very high — **no obvious solution**

- ESA policy initially to reduce contact between DPAC and Astrium (who construct Gaia) **not good**

- External

- ▶ perhaps could have had a better DPAC website
- ▶ ESA PR also not great (ok as they point out they have a tiny fraction of NASA budget)
- ▶ LSST.org is very nice.
- ▶ **Publication policy was dealt with very late**

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# Operations Rehearsals

- Have had 4 operations rehearsals in the last 2 years
- Not tests as such; intended for training staff and checking procedures
- Move the teams mind-set away from just development and towards building a usable system.
- Helped find defects as well as other needs (missing features and functions) in the software running at DPCs.
- These are good **could have started earlier**
- **It became clear operational awareness was low across DPAC, i.e. in terms of turn around of commanding to Gaia and how it works, how data flows, general constraints of satellite operations**

# Requirements Management

- Some requirements at an appropriate level are very useful.
  - ▶ could have been better formulated
  - ▶ separation of performance, software, and science requirements should have been clearer
- DPAC stayed away from requirements tools like DOORS though
- Used macros in LaTeX for requirements and scripts to build trace tables
- All requirements and test reports then ingested in the Information Management Tool (2012)
- Could probably have put more effort in this earlier
  - ▶ might then have decided to start up some CUs later.
- Reviews are an unavoidable part of all this
  - ▶ ESA reviews are too formal and too large
  - ▶ External reviewers like Innocente (VI-001,VI-002) very good — would be good to have a few external review *partners*



# Management and science I

All large projects, and especially science projects, have management *issues*

- In 2006 we had a big management training week for the DPAC management — though sceptical to start most found it good
- Science project management is a little different but still books like (Handy, 1993) are quite useful
- Cyclic (Agile type) development seems well suited to science
  - ▶ we chose six month cycles — probably too long
  - ▶ **some prototypes started real early** (O'Mullane & Lindegren, 1999)
  - ▶ we have great simulations — they started in 1998 before Gaia was accepted
    - ★ Still they always seemed to be a little behind what people wanted — **we have no solution for that, could not start earlier**
    - ★ simulator fell out of the ECSS rigour — testing etc. . .

## Management and science II

- ▶ we did a lot of testing; some tests were probably not appropriate in hindsight
- ▶ despite aiming for test driven development — NOT ENOUGH effort in testing and many systems only recently got continuous integration
- Scientific institutes are not good at managing things like software projects (hard anyway)
  - ▶ Interface control between software was insufficient — data model was not enough
  - ▶ Perhaps ESA should have taken control of all critical software
  - ▶ ESA is stepping back from this type of role in future missions and was not totally happy about the level of involvement of ESAC in DPAC.
- Note: industrial contracts for scientific software are difficult
  - ▶ but science consortia need managers and engineers earlier
  - ▶ Did an experiment with this on Gaia very early on
  - ▶ XMM have there own woeful tale to tell

- ▶ Still CNES have been *stuck* with this model — even worse as we drive the project quite dynamically.



At ULB Belgium - yes we will stand on our hands if we need to.  
DPACE is small and technically focused. Meeting about twice a year.

- Started out with the idea of limited number (9) of decoupled Coordination Units(CU) — Good
  - ▶ this resulted from much discussion in the DACC — It was good to have dedicated group to decide how the consortium was set up; n.b. DACC≠DPACE
  - ▶ Having relatively small executive (DPACE) being technically focused was also good
  - ▶ All in DPACE may not have agreed with all decisions but ALL backed them once made
- Data processing centres added under CUs — also a bit decoupled — Could have been more coupled and better controlled
  - ▶ DPCs often started too late
    - ★ led to a lack of *engineering* in many areas — lack of software engineers in initial phases, many hires were astronomers
    - ★ performance aspects of the systems were handled too late
    - ★ integration efforts were underestimated

- ▶ CUs turned out not to be so decoupled in software, e.g. data models need to be the same. . .
- ▶ May have been a mistake to allow different frameworks/DBMSs in different DPCs
  - ★ certainly inefficient in effort terms
  - ★ however it is too easy to make things NOT work — I did not want to *force* everyone down the route I followed
- despite starting with a management course — Management support was insufficient
  - ▶ More management support in setting up the CUs and reporting would have been good — **perhaps more emphasis should have been put here by DPACE**
  - ▶ The Project Office (PO) came along too late to assist with shaping this — it was good and should have started earlier
- Too collaborative?

## DPAC Management III

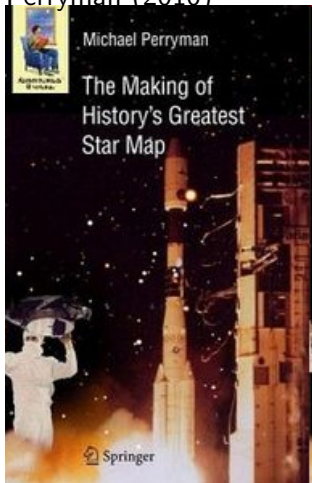
- ▶ DPAC was broadly inclusive — CU leaders on paper had the chance to include or not groups and WPs but in fact no one was left out
- ▶ this has lead to some inefficiencies — perhaps we could be smaller and more focused
- ▶ we possibly should have jettisoned some work packages, groups, and individuals early on
- ▶ In a proper phased approach some CUs could probably have started 2 years later with minimum presence at kick off
- Too flexible and too inflexible
  - ▶ there are many configuration control boards and other groups to manage change
  - ▶ no one wants any change to anything — *until the moment they want a change then it should be immediate*
  - ▶ We have found no solution to this
- In hindsight some work packages were misplaced

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## Conclusion

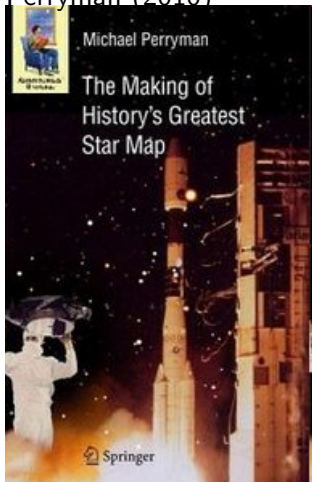
Perryman (2010)



- many of us dreamed of a Gaia Processing Institute - only a dream for us; but for LSST !!
- Much mentioned here is contentious — others do not see it exactly as I do.
- For me DPAC started off well largely due to strong initial leadership especially from Perryman
- All agree we are fortunate to have some excellent people in DPAC
- thanks to DPAC for their input to this presentation and to DPAC for all their work over the past years.
- How this all works out will soon be seen... probably a tough year ahead !

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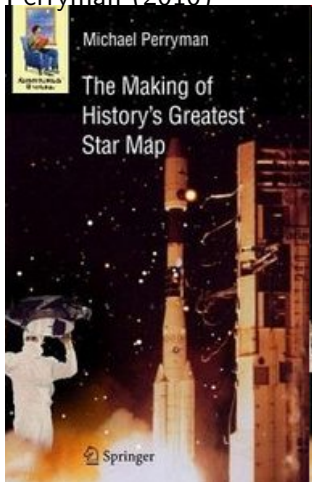
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## 5 Acronyms

## 6 References

The following table has been generated from the on-line Gaia acronym list:

Acronym	Description
CNES	Centre National d'Etudes Spatiales (France)
CU	Coordination Unit (in DPAC)
DACC	Data Analysis Coordination Committee (obsolete)
DPAC	Data Processing and Analysis Consortium
DPACE	Data Processing and Analysis Consortium Executive
DPC	Data Processing Centre
EC	Economic Conditions
ECSS	European Cooperation for Space Standardisation
ESA	European Space Agency
ESAC	European Space Astronomy Centre (VilSpa)
ESF	European Science Foundation
ESTEC	European Space research and TEchnology Centre (ESA)
FOP	Flight Operation Procedure (Plan)
GIS	(Astrometric) Global Iterative Solution
GPDB	Gaia Parameter DataBase
GPL	GNU Public License
IoA	Institute of Astronomy (Cambridge; also denoted IOA)
LDAP	Lightweight Directory Access Protocol
LGPL	Lesser General Public License
LSST	Large-aperture Synoptic Survey Telescope
LaTeX	(Leslie) Lamport TeX (document markup language and document preparation system)
MDB	Main DataBase

# Acronyms II

MOC	Mission Operations Centre
NASA	National Aeronautics and Space Administration (USA)
PO	(DPAC) Project Office
PR	Progress Report
QA	Quality Assurance
SOC	Science Operations Centre
SVN	SubVersioN
TOC	Table of Contents
ULB	Université Libre de Bruxelles (Belgium)
WP	Work Package
XMM	X-ray Multi-mirror Mission (ESA; officially known as XMM-Newton)

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- [BAS-003], Bastian, U., 2007, *Reference systems, conventions and notations for Gaia*,  
GAIA-CA-SP-ARI-BAS-003,  
URL <http://www.rssd.esa.int/cs/livelihood/open/358698>
- Comoretto, G., Gallegos, J., Els, S., et al., 2012, In: Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series, vol. 8449 of Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series, ADS Link
- de Bruijne, J.H.J., Lammers, U., Perryman, M.A.C., 2005, In: C. Turon, K. S. O'Flaherty, & M. A. C. Perryman (ed.) The Three-Dimensional Universe with Gaia, vol. 576 of ESA Special Publication, 67–+, ADS Link
- [RD-010], Drimmel, R., Els, S., O'Mullane, W., et al., 2014, *DPAC Project Development Plan*,  
GAIA-CD-PL-INAF-RD-010,  
URL <http://www.rssd.esa.int/cs/livelihood/open/2786669>
- [ESA-SCI(2000)4], GAIA Science Advisory Group, 2000, *GAIA. Composition, Formation and Evolution of the Galaxy [The GAIA Study Report (ESA-SCI(2000)4)]*,  
ESA-SCI(2000)4,  
URL <http://www.rssd.esa.int/cs/livelihood/open/359232>
- Handy, C., 1993, *Understanding organizations*, Penguin Books, London, England New York, N.Y., USA
- [JH-001], Hernandez, J., 2014, *Main Database Interface Control Document*,  
GAIA-C1-SP-ESAC-JH-001,  
URL <http://www.rssd.esa.int/cs/livelihood/open/2786145>
- [VI-001], Innocente, V., 2007, *External review report for Gaia SOC/DPAC SRR*,  
VI-001,  
URL <http://www.rssd.esa.int/cs/livelihood/open/2803649>
- [VI-002], Innocente, V., 2009, *External review report for Gaia SOC/DPAC DR*,  
VI-002,  
URL <http://www.rssd.esa.int/cs/livelihood/open/2905956>



## References II

- [WOM-003], O'Mullane, W., 2005, *Large scientific data systems - analysis of some existing projects and their applicability to Gaia*,  
GAIA-C1-TN-ESAC-WOM-003,  
URL <http://www.rssd.esa.int/cs/livelihood/open/497678>
- [WOM-019], O'Mullane, W., 2007, *CU1 Progress Report #1*,  
GAIA-C1-PR-ESAC-WOM-019,  
URL <http://www.rssd.esa.int/cs/livelihood/open/2803205>
- [WOM-001], O'Mullane, W., Lammers, U., 2007, *Work breakdown structures for DPAC*,  
GAIA-C1-TN-ESAC-WOM-001,  
URL <http://www.rssd.esa.int/cs/livelihood/open/497865>
- O'Mullane, W., Lindegren, L., 1999, *Baltic Astronomy*, 8, 57, [ADS Link](#)
- O'Mullane, W., Luri, X., Parsons, P., et al., 2011, *ArXiv e-prints*, [ADS Link](#)
- Perryman, A., 2010, *The Making of History's Greatest Star Map*, Astronomers' universe, Springer,  
URL <http://books.google.es/books?id=P-5pZ8GNuPIC>