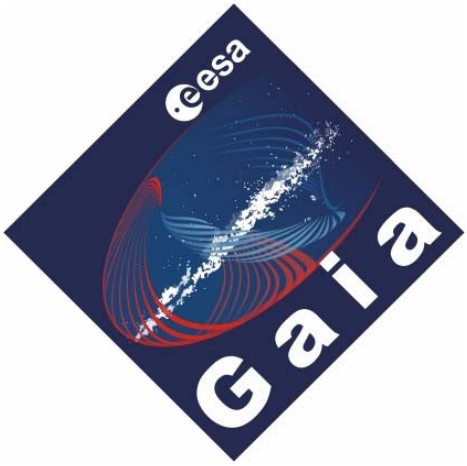
Announcement of Opportunity

for the

Gaia Data Processing



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1. Introduction

In January 2005, ESA issued a call for Letters of Intent (LoI) to gauge the potential participation of the community to the Gaia data processing effort. By the deadline of 20 March 2005, a total of 177 Letters had been received, a synopsis of which was presented to the AWG at its 21-22 April 2005 meeting. The Gaia Science Team nominated a 'Data Analysis Coordination Committee' (DACC) to further analyse the LoIs, propose a preliminary structure for the Data Processing framework, including a first assessment of the role of ESA, and catalyse the preparation of the response to the planned ESA Announcement of Opportunity.

This analysis work has been concluded on 23-24 May 2006 at a meeting of the above mentioned DACC, where it was concluded that a potentially successful structure and consortium could be formed by the parties having responded to the call for Letters of Intent. This conclusion was confirmed by the Gaia Science Team (GST) at its 17th meeting on 14-15 June 2006 at ESTEC, The Netherlands.

This Announcement of Opportunity (AO) defines the context and conditions which will allow a consortium to respond.

The Gaia Science Management Plan (SMP, ESA/SPC(2006)45) defines the top-level scientific management of the Gaia mission and describes the respective roles of all parties involved. The SMP is an applicable document and as such has been included in the AO data package. Where and when relevant, the SMP takes precedence over what is described in this AO.

2. Summary

This summary aims to describe the top level scientific objectives of Gaia as well as a concise description of the Gaia mission and satellite and the mission operations and data processing ground segment. It further details a top level work breakdown (as detailed by the DACC and approved by the GST) and the miscellaneous ESA contributions to the Gaia data processing.

Scientific Objectives: Gaia is a space astrometry mission, a broad survey project following the measurement and operational principles of Hipparcos. It will help solving one of the most difficult yet deeply fundamental challenges in modern astronomy: to create an extraordinarily precise three-dimensional map of about one billion stars throughout our Galaxy and beyond. In the process, it will map their three-dimensional motions, which encode the origin and subsequent evolution of the Galaxy. Through comprehensive photometric and spectroscopic classification, it will provide the detailed physical properties of each star observed: characterising their luminosity, temperature, gravity, and elemental composition. This massive stellar census will provide the basic observational data to tackle an enormous range of important problems related to the origin, structure, and evolutionary history of our Galaxy.

Using on-board object detection, Gaia will survey more than one billion stars at the few micro arc-seconds level accuracy, complete to 20th magnitude, with extensive multi-colour multi-epoch photometry and spectroscopic measurements. The formal scientific

requirements are included in the Mission Requirements Document [GAIA-EST-RD-00553].

Mission and Satellite: The space segment is characterised by:

- a 3-axis stabilized satellite, operated at the Lagrange point L2;
- systematic scanning of the sky at a constant angular velocity according to a well-defined scanning law;
- a high-stability payload which systematically and repeatedly measures the astrometric, photometric and spectroscopic properties for some 1 billion celestial objects;
- on-board detection of each object brighter than a given signal-to-noise ratio at the observation epoch;
- a commensurate telemetry rate of some 1–5 Mbps.

Mission Operations Ground Segment: The mission operations ground segment is composed of the Mission Operations Centre (MOC) located at ESOC, and the associated ground stations and communication links. The Mission Operations Centre is responsible for all spacecraft mission operations, including: spacecraft status monitoring; payload health monitoring; spacecraft control; mission planning of spacecraft and payload activities; orbit determination and control; attitude determination and control; on-board software maintenance; and transmission of the raw satellite data to the data processing ground segment.

Data Processing Ground Segment: The data processing ground segment comprises a single processing pipeline leading directly to the intermediate and final mission products. The underlying principles of the data processing have been developed by the Gaia scientific community over several years. It is the details of this task that is described in this AO, and will consist of a collaboration between the ESA Gaia Science Operations Centre (SOC) and a substantial and broad scientific community.

Tentative Organisational Structure: The GST has approved a draft organisational structure for executing the Gaia data processing task, and this has been used by ESA to scope and describe its contributions to the Gaia data processing. It is anticipated that the final structure will be formalised through the community's response to this AO.

The activities of the consortium are assumed to be structured around a number of Coordination Units (CU) and associated Data Processing Centres (DPC), together responsible for the production and operation of the Gaia data analysis system.

The Data Processing and Analysis Consortium (in this document referred to as DPAC) is expected to be coordinated by a committee (in this document referred to as the DPAC Executive = DPACE), nominated by the data processing consortium itself and led by a nominated representative from the scientific community. The precise role of this committee and its interaction with ESA are described in the SMP.

The data processing consortium as a whole (i.e. including the ESA provided elements) will be responsible for the development of the computer systems required for the processing of Gaia science data in order to fully support the scientific goals of the mission. This will include development and testing of the computer systems according to agreed standards and guidelines; management of the transition from development to

operations of its systems; and maintenance of the systems until the end of the post-operational phase.

This consortium will also be responsible for the operation of these processing systems. These activities are to: (a) provide the operational environment for the processing systems; (b) operate the processing systems during the routine operations and post-operational phases; (c) deliver data products in a timely manner, consistent with the overall data processing schedule; (d) report anomalous system behaviour of the processing systems to the developers of the processing systems, such that it may be corrected without unnecessary delay.

The Coordination Units (CU) are proposed as follows (NOTE: CU9 is *NOT* part of the current AO, but is listed for completeness. It will be part of a later, separate, AO at a point in time commensurate with a more mature view of the actual Gaia data products and required access mechanisms. It should be noted that the CU9 AO will contain an explicit condition that the work is to be executed in full (proven) agreement with the consortium solicited through the current AO)*:*

CU1: System Architecture: This CU is responsible for the system architecture to be used within the DPAC, including: (a) definition of the system architecture; (b) definition and coordination of the development and operational environments, including software, hardware and database technology; (c) definition and execution of the end-to-end system testing; (d) tailoring of ECSS standards and definition of Quality Assurance procedures; (e) provision of the central Gaia database, dissemination of data to the DPCs and integration of results.

CU2: Data Simulations: Validation and verification of the DPAC system(s) requires detailed simulated data for all aspects of the Gaia mission, and at various levels of detail, including the astronomical, spacecraft and instrument contributions to: (a) low-volume high-fidelity instrument simulations; (b) high-volume telemetry stream simulations for all instruments; (c) higher level data relevant for validation by each CU. CU2 will develop and maintain the simulator throughout the project lifetime.

CU3: Core Processing: The core processing tasks provided include to: (a) unpack, decompress, and process the science data retrieved from MOC to provide rapid (approximately 1 day) monitoring (and feedback to ESOC) of the spacecraft and payload performances at the ultra-precise accuracy levels targeted by the mission; (b) provide the astrometric global iterative solution; (c) contribute to key parts of the reduction of the science data and the generation of the final products (pre-processing and core-processing tasks); (d) periodically re-process raw telemetry, taking advantage of improved calibration data and reduction systems; (e) assist with instrument characterization and calibration.

CU4: Object Processing: The object processing tasks include processing the astrometric and photometric data for more complex objects not handled by the astrometric core processing, specifically: (a) non-single stars (binary and multiple stars); (b) Solar System objects (asteroids, near-Earth objects, etc); (c) extended objects.

CU5: Photometric Processing: Photometric processing tasks include: (a) basic calibrations, photometric parameters, calibration model; (b) accumulation of mean flux information and epoch photometry; (c) pass-band characterisations and absolute flux calibrations; (d) variability detection; (e) flux-based and classification-based science alerts; (f) image restoration in 2d.

CU6: Spectroscopic Processing: Spectroscopic processing tasks include: (a) spectral extraction and background correction; (b) data sanity check and quick calibrations; (c) nominal calibrations and meta-processing; (d) single star radial and rotational velocities determination.

CU7: Variability Processing: Variability processing tasks include: (a) variability classification, period search and variability models; (b) feedback of variability analysis on the calibration models; (c) catalogue exploration and checks of the variability database; (d) statistical analysis of the data; (e) external observation coordination; (f) variability announcements.

CU8: Astrophysical Parameters: Astrophysical parameter determination tasks include: (a) classification of discrete sources; (b) photometric and spectroscopic stellar parameterization; (c) treatment of interstellar extinction; (d) object cluster analysis; (e) luminosity, age and mass estimation.

CU9: Catalogue Access: The final mission products deliverable to the wider scientific community, and the corresponding schedule of deliverable data products, has not yet been established. Certain photometric results should be released rapidly, close to real-time where feasible, to allow the follow-up of phenomena such as bursts, supernovae, and gravitational lensing events. CU9 will be set up in the future to provide: (a) archive and interrogate systems for Gaia data products; (b) systems to make Gaia data products publicly available; (c) visualisation tools for Gaia data products; (d) tools and documents describing the Gaia data products and their interrelation.

Data Processing Centres (DPC): A small number of major Data Processing Centres are expected to be responsible for the operations of the Gaia data analysis system. It is anticipated that each of these data processing centres could serve the processing needs of up to a few CU's. The central data processing and data transfer hub will be supplied by ESA and located at ESAC (Madrid, Spain.

ESA Commitments: ESA is committing a substantial contribution to the ground data processing. It will consist of the Gaia project scientist, his deputy and the Gaia Science Operations Centre (SOC; located at ESAC) which will be responsible for a number of tasks critical to the timely reduction of all Gaia data, specifically:

- the overall processing system architecture;
- the development, integration, testing and operation of the data reception and archiving system;
- hosting, operation and maintenance of the main data base;
- the execution of the astrometric global iterative solution;
- data transfer to and from the external processing centres;
- definition and execution of end-to-end system testing;
- technical support in definition and production of the final catalogue;
- hosting the final catalogue archive and user access;
- acquisition, maintenance and operation of all the hardware and infrastructure required for the above tasks.

In addition, the SOC will be involved, in collaboration with the community, in the development of the astrometric global iterative solution.

Taking due account of the above defined undertakings, the ESA SOC at ESAC will form part of the Data Processing and Analysis Consortium.

3. Data Processing Science Implementation Requirements

The implementation of the Gaia scientific ground segment, including the data processing consortium sought for through this AO, will be detailed in the Science Implementation Plan (SIP). This SIP will consist of:

- The Data Processing Implementation Plan
- The SOC (and PST team) implementation plan

The former will essentially consist of the proposal submitted in response to this AO, and the latter will be added (in coordination with the DPACE) once a proposal has been selected.

Implementation of the science requirements shall be compatible with the overall programmatic, schedule and budgetary constraints applicable to the Gaia Programme. During the design and development phases (Phase B and C/D) the requirements encompass all tasks required for the provision of the necessary Gaia science operations facilities. During the operational phase (Phase E), the requirements encompass all tasks required to carry out Gaia science operations in the optimal way compatible with the available resources. For the post-operational phase, the requirements encompass all tasks required to build the final output of the Gaia mission, but do not (yet) cover the archive phase.

3.1 Functional Requirements

Data Processing and Analysis Consortium: These top-level requirements apply to the consortium and global mission products as a whole.

FUNC-3.1-1 The DPAC shall develop all algorithms and processing systems required for the scientific processing of Gaia data and the production of all Gaia products.

FUNC-3.1-2 The DPAC shall provide all infrastructure required for their processing systems, also integrating those elements provided by ESAC.

FUNC-3.1-3 The DPAC shall operate the processing systems until the final Gaia products are produced and validated.

FUNC-3.1-4 The DPAC shall validate and document the intermediate and final Gaia products.

FUNC-3.1-5 The DPAC shall define the milestones and schedule for the data reduction activities, in accordance with the project scientist and the Gaia Science Team.

FUNC-3.1-6 The DPAC shall produce intermediate and final Gaia products, according to the schedule and content defined in accordance with the project scientist and the Gaia Science Team.

FUNC-3.1-7 The final Gaia products shall consists of at least astrometric, photometric and spectroscopic data with accompanying interrogation tools. Access tools and mechanisms will be defined at a later date (within CU9; see section 2).

Gaia Data Processing Hub: The following requirements refer to the provision by ESA of the central data distribution hub at the ESA SOC at ESAC, hereafter referred to as “the hub”.

FUNC-3.1-8 The DPAC shall assign to one centre, the hub, responsibilities for the single point of contact with the ESA Project Team (involving the project scientist where and when appropriate) during the development phase (up to and including commissioning), and with the MOC and the mission manager during the operational phase.

FUNC-3.1-9 The hub shall receive and process telemetry from the MOC.

FUNC-3.1-10 The hub shall provide feedback to the MOC of required changes to the timeline resulting from first look analysis of the science telemetry.

FUNC-3.1-11 The hub shall provide updated calibration information to the MOC.

FUNC-3.1-12 The hub shall define the Interface Control Document governing periodic data transfer between the hub and the DPCs, and vice versa.

FUNC-3.1-13 The hub shall periodically send data to the DPCs according to the governing Interface Control Document and to the schedule referred to in FUNC-3.1-5 and FUNC-3.1-6.

FUNC-3.1-14 The hub shall integrate reduced science data from the DPCs according to the defined and agreed integration rules.

FUNC-3.1-15 The hub shall be the primary point of distribution of all intermediate and final Gaia products.

FUNC-3.1-16 The hub shall provide archive and interrogation systems for intermediate and final Gaia products.

Coordination Units and Data Processing Centres: These requirements apply assuming the distribution of work over the so-called Coordination Units (CU’s), as defined in section 2. Should an alternative DPAC structure be proposed, full compatibility shall be demonstrated.

FUNC-3.1-17 The CUs shall develop, validate, and document the processing systems according to their defined role.

FUNC-3.1-18 The CUs shall deliver the processing systems to the relevant DPC.

FUNC-3.1-19 The CUs shall maintain their processing systems until the final Gaia products are produced and validated.

FUNC-3.1-20 Data Processing Centres shall be responsible for the integration and operation of the processing systems under their remit.

FUNC-3.1-21 The Data Processing Centres shall receive and process data from the hub according to their defined function.

FUNC-3.1-22 The Data Processing Centres shall send the newly-reduced science data to the hub for integration, according to the schedule defined by the DPACE.

3.2 Performance and Availability Requirements

PERF-3.2-1 The Data Processing Ground Segment facilities shall be sufficient to produce all intermediate and final Gaia products according to the agreed schedule, in particular the final Gaia data products shall be available within three years after the end of the operational phase of the mission.

PERF-3.2-2 The Data Processing Ground Segment facilities shall be dimensioned in such a way that they can support without re-design an extension of at least one year of the in-orbit operations.

PERF-3.2-3 The overall availability figure for the Processing Systems, and connectivity to these systems, as located at the Gaia hub, shall be 95% minimum.

3.3 Product Assurance and Quality Assurance Requirements

The purpose of the PA/QA activity is two-fold: (a) it ensures during each phase conformity of the outputs with the inputs from a previous phase, and ensures traceability from requirements to design for both hardware and software elements; (b) it ensures adherence to the standards established for the Gaia mission, and in particular that all hardware and software elements of the ground segment implementation will comply with all mission requirements.

General: These general requirements are applicable to all the entities which contribute to the preparation and execution of the Gaia operations.

PAQA-3.3-1 During all phases of the Gaia mission implementation (i.e., design, development, integration and test of the total ground segment both hardware and software) each contributor shall carry out a Product Assurance/Quality Assurance (PA/QA) activity.

PAQA-3.3-2 The PA/QA activity shall also be exercised throughout the operations phase of the mission to ensure that all changes to Processing Systems are carried out in accordance with a formal change control procedure.

PAQA-3.3-3 The PA/QA aspects shall be addressed at each review of the various components (i.e., hub and DPCs) of the Ground Segment as well as during the reviews of the entire Ground Segment and the Mission Level reviews.

PAQA-3.3-4 The DPAC shall (as part of the PA/QA function) carry out a risk assessment of their overall activities. Practical risk mitigation measures shall be identified and implemented. The status shall be reported as part of regular reporting. This aspect shall be addressed on the occasion of the relevant reviews.

Documentation:

PAQA-3.3-5 Requirement specifications, design specifications, test specifications, interface control documents and user manuals shall be produced as required.

PAQA-3.3-6 Implementation plans and procedures, test plans and procedures, and operations plans and procedures shall be produced for all Processing Systems produced by the DPAC.

PAQA-3.3-7 Software documentation shall conform to the ECSS standards. The ECSS standards must be tailored to each individual project's need. It is foreseen in the CU1 activities that the hub will carry out this tailoring process as part of its contribution to the DPAC. It is assumed that the DPAC as a whole will conform to the SOC (and Gaia project) tailored standards.

PAQA-3.3-8 The Gaia Ground Segment documentation, which must be accessible to all participants in the programme, shall conform to the electronic standards defined for the Gaia project. These standards will be defined and agreed jointly by the DPAC, MOC, project scientist and the Gaia Project.

Test Requirements: The following test requirements are applicable to the DPAC.

PAQA-3.3-9 All operational science functions of the Gaia Data Processing Ground Segment shall be tested and validated before launch.

PAQA-3.3-10 Subsystem and system tests shall be conducted according to approved test plans and test reports shall be issued.

PAQA-3.3-11 The operational elements of the Data Processing Ground Segment (hub and DPCs) shall be included, as required, in the Satellite Verification Tests in order to verify their interfaces with the satellite and the other elements of the ground segment.

PAQA-3.3-12 The operational elements of the Data Processing Ground Segment shall, where relevant, be included in the end-to-end tests which validate proper operations of the entire space-ground segment system.

Configuration Control:

PAQA-3.3-13 The hardware configurations (computers, work-stations, peripherals, LANs, communication equipment, etc.) of the operational elements of

the Data Processing Ground Segment shall be maintained under configuration control according to the usually applicable ESA standards.

PAQA-3.3-14 All DPAC processing systems, documentation and data items shall be delivered for integration and archiving in accordance to the DPAC configuration control system.

PAQA-3.3-15 The DPAC implementation shall be carried out in accordance to a (common) Software Project Management Plan to be produced by the Gaia SOC in agreement with the DPAC.

PAQA-3.3-16 All DPAC processing systems elements shall be produced in accordance to a (common) Software Quality Assurance Plan to be produced by CU1 (and overseen by the Gaia SOC as part of the ESA contribution to CU1) in agreement with the DPAC. The Software Quality Assurance Plan shall specify software coding standards applicable to the DPAC.

3.4 Management Requirements

Top Level Responsibilities: The Gaia Ground Segment architecture is based upon a decentralised architecture. The allocation of responsibilities for the monitoring, management, coordination and implementation of the tasks specified in this document reflects this structure.

MNGT-3.4-1 The SOC development manager, who has the delegated responsibility for all SOC related matters, shall ensure timely delivery of all the SOC deliverables and timely execution of all SOC tasks specified in this document. In practice actual activities will be coordinated with the project scientist.

MNGT-3.4-2 The DPACE shall be responsible for the monitoring of the DPAC activities in order to verify that the tasks specified in this document are carried out according to specification and schedule.

MNGT-3.4-3 The DPACE will liaise with the Project Team through the project scientist and the SOC team to verify that the tasks specified in this document are compatible with the overall Ground Segment development schedule.

MNGT-3.4-4 In response to the requirements specified in this document the DPAC shall issue a proposal (hereafter referred to as “the proposal”) to ESA. Contingent upon the acceptance of this proposal, this proposal will become the data processing part of the Science Implementation Plan (SIP; see section 3.). The SIP shall serve for monitoring progress of the tasks identified therein.

MNGT-3.4-5 Any change in the contents of the SIP (i.e. the proposal), after its acceptance, might imply changes in cost, schedule and/or performance of the corresponding science function; therefore any modification to the SIP, or tasks, or baseline identified therein shall be formally reviewed and approved by ESA.

Planning Requirements:

MNGT-3.4-6 The proposal shall the define the schedule and plan for completion of Gaia data processing by the DPAC, including as a minimum (a) the overall schedule for activites of the DPAC; (b) the definition of the work packages; (c) the schedule for the complete set of work packages supported by the corresponding schedule planning; (d) the identification of the cost-driving parameters and the corresponding estimates of resources spread over time (manpower, computers and other investment and running expenditure);

MNGT-3.4-7 Each work package defined in the proposal shall include the definition of (a) the objective of the work package; (b) the corresponding inputs and output; (c) deliverable items; (d) progress measurement points; (e) start and completion criteria; (f) the manpower (in man-months) required for the work package.

Reporting Requirements:

MNGT-3.4-8 The proposal shall define in detail the reporting mechanisms. These reports (hereafter referred to as "management reports") shall be produced on a regular (typically quarterly) basis in a format and frequency to be agreed with ESA.

MNGT-3.4-9 Management reports shall be prepared by each CU and DPC. These reports shall be included in the reports to ESA (see MGMT-3.4-12) together with an overall DPAC and DPACE summary report.

MNGT-3.4-10 Management reports shall include the following information: (a) brief summary of the progress achieved since the previous reporting period; (b) concise description of the main problem areas, their criticality and anticipated impacts (e.g., delays in the schedule or non conformance with the requirements); (c) status of the technical design, of proposed solutions to the problem areas and of engineering, product assurance and testing activities; (d) overall manpower availability and usage, showing actual versus planned; (e) update of the overall schedule with latest prediction of the completion dates of the identified milestones; (f) a list of relevant action items and their status.

MNGT-3.4-11 The managers of the relevant sub-units (CUs) of the selected consortium have standing invitations to the Gaia Science Team meeting with the status of observer. It is expected that these activities be foreseen in the proposed work breakdown structure and provide the budget to support this.

MGMT-3.4-12 The activities and schedule of the CUs and DPCs are coordinated by the DPACE. The DPACE should have the authority to represent the DPAC and take executive decisions on its behalf. The DPACE reports to the project scientist (who in this respect represents an ESA internal DPAC oversight group) and through him to the Gaia Science Team.

4. Proposal submission details and evaluation timeline

Proposals shall be submitted electronically to:

http://www.rssd.esa.int/Gaia

In parallel the original, signed version shall be submitted to

Dr. Fabio Favata
Astronomy and Fundamental Physics Missions Coordinator
ESA
Rue Mario Nikis 8-10
75015 Paris
France

Also 7 paper copies shall be submitted to:

Dr. Fred A. Jansen
Gaia Project Scientist
ESTEC SCI-SA
P.O. Box 299
2200 AG Noordwijk
The Netherlands

In addition a copy of the complete proposal must be sent to each of the funding agencies which will later be requested to provide financial support to the DPAC activities.

Proposals shall at least contain the following:

- Executive Summary
- Main Proposal
  - Description of Gaia and its science
  - Proposed data processing approach (logistics and algorithmic approach)
  - Consortium breakdown
  - Structure and authority of consortium executive
  - Reporting structure proposed
  - Work breakdown structure and associated details (detailed planning timeline etc.)
  - Statement of compliance with the SMP and the terms and conditions of this AO.
- Detailed funding proposal:
  - Brief description of qualification and experience of the DPACE members and the CU managers.
  - Contact details and area(s) of involvement of all current DPACE and DPAC members
  - Estimated breakdown of manpower per participating country
  - Signed initial letter(s) of commitment from the relevant (national) funding authorities, indicating financial and manpower agreements. Where, for very clearly defined and specified reasons, such commitments are not yet

available, a roadmap of how such funding will be secured should be identified.
  - A list of funding authorities to which the proposal has been sent (see above).

The timetable foreseen for the approval cycle is specified in the SMP.

The submitted proposal(s) shall be reviewed by an evaluation committee appointed by the Director of Science.

They shall evaluate the quality of the submitted proposals primarily based on:

- Scientific quality and completeness of the analysis and proposed processing
- Background and expertise of the proposed participants
- Adequacy of resources assigned to development, processing and management
- Compliance with the SMP and AO

It is anticipated that a clarification meeting between ESA and the proposing parties shall be held on 15 January 2007 (at ESTEC).

It should be noted the following selection of the successful consortium, a negotiation process between ESA and the (national) funding agencies is foreseen. These negotiations should result in a multilateral agreement (MLA, to be approved by ESA council), identifying the willingness of all parties involved to fund the proposed activities such as to allow achieving the goals of the Gaia data processing as specified in the proposal.

Further questions on the AO itself, or on the associated approval process, should be addressed by E-mail to:

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Or to

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