Distributed Intelligence for Cost-Effective and Reliable Distribution Network Operation

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Executive summary

The world of the Distribution System Operator is changing.

Energy use patterns become more variable with increasing use of low carbon technologies such as distributed renewable energy and electric vehicles, placing a new set of technical requirements on networks traditionally designed for centralised power distribution and predictable load patterns.

In parallel, the maturing range of Information and Communication Technology (ICT) solutions now available make it possible for data to be captured and analysed across the network in ways that were previously not possible, and to control and automate more aspects of the energy system.

DSOs retain the responsibilities of providing secure and reliable networks, ensuring a high quality of supply to customers and delivering this service in a cost-effective manner. To achieve these aims, DSOs need to change the ways distribution grids are designed, operated and maintained to accommodate, and take full advantage of, these new technologies.

This multi-dimensional challenge is at the heart of DISCERN.

The DISCERN consortium of eleven project partners is drawn from DSOs, technology providers, research institutes and consultants.

The partners have collaboratively developed novel decision support tools designed and tailored to meet real world requirements, and applied these in conjunction with a family of innovative technological solutions for monitoring and controlling LV and MV networks.

Information from the five DISCERN Smart Grid demonstration sites is complemented by the use of simulations to provide detailed analysis of the range of Smart Grid functionalities investigated. A framework for using Key Performance Indicators (KPIs) to assess solutions is provided, and the scalability and replicability of the technologies trialled has been evaluated to determine the factors of relevance for their cost-effective and reliable deployment and operation by other DSOs.

The SGAM and Use Case methodologies and tools developed within DISCERN provide an intuitive approach for communicating and building a common understanding of Smart Grid solutions, allowing DSOs to adopt and adapt solutions in keeping with the DISCERN '3L' approach (Leader, Learner and Listener DSOs).

The suite of DISCERN methodologies and tools have proven to be of great value in supporting knowledge sharing between all relevant stakeholders. Detailed information on the solutions trialled can be exchanged in a clear and consistent way, supporting DSOs and others within the electricity sector in designing, implementing and assessing Smart Grid solutions in a structured and collaborative manner to deliver benefits for networks across Europe.

While each distribution network across Europe will have its own specific characteristics, the DSOs share common aims and challenges. The reusable methodologies and tools developed through DISCERN can be readily adopted by DSOs to help determine optimal levels of intelligence for their specific grids and network context with a greater level of confidence.

In addition to the tools and information on the specific technologies trialled, the experiences from DISCERN have been clearly documented to create a comprehensive series of recommendations to the following groups:

- Distribution System Operators;
- Vendors and Technology Providers;
- Standardization Bodies;
- the European Commission;
- National Policy Makers, and
- Scientific Institutions and Consultants.

Electricity networks are key to providing the European economy with a high quality power supply that supports the competitiveness of European industry and helps the EU to meet its goals of increasing energy generation from renewable sources and reducing levels of carbon emissions to combat climate change.

Smart networks, using advances in communications, monitoring and automation technology to operate in a more sophisticated and efficient way are necessary to meet the challenge of accommodating low carbon energy technologies within distribution networks whilst maintaining security of supply and minimising the cost to the customer.

Through the introduction of advanced functionalities supported by enhanced levels of monitoring, Smart Grid solutions will:

- support capex deferral through ‘optioneering’, allowing DSOs to operate networks securely as more is learnt about how energy usage patterns are changing, potentially avoiding significant investment in reinforcement;
- provide flexibility in network operation, allowing fault situations to be managed effectively and enabling new load or generation to connect to the networks more quickly or at lower cost, and
- support management of thermal and voltage network constraints, which can improve asset health and longevity, and enhance the levels of service experienced by customers.

DISCERN provides DSOs and other industry participants with tools and knowledge to inform their decisions on the planning, design and operation of future networks, and provides recommendations to a range of stakeholders involved with the promotion, design, manufacture and delivery of Smart Grids to ensure a secure and high quality supply for the future.

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Abbreviations and Acronyms

Table 1 Acronyms

AMR	Advanced Meter Reading
CAPEX	Capital expenditures
CBA	Cost-Benefit-Analysis
COM600	all-in-one communication gateway, automation platform and user interface solution for utility and industrial distribution substations
DSO	Distribution System Operator
EEGI	European Electricity Grid Initiative
EU	European Union
FPI	Fault Passage Indicator
HEC	Home Energy Controllers
ICT	Information and Communication Technology
IED	Intelligent Electronic Devices
IBDR	Iberdrola
KPI	Key performance indicator
LV	Low voltage
MV	Medium voltage
NTVV	New Thames Valley Vision
OPEX	Operational Expenditures
RWE	RWE Deutschland
SCADA	Supervisory Control and Data Acquisition (Control centre application)
SGAM	Smart Grid Architecture Model
SM	Smart Meters
SmOp	Smart Operator
SS	Secondary Substation
SEPD	Scottish and Southern Energy Power Distribution
SWOT-Analysis	Analysis of Strengths, Weaknesses Opportunities and Threats
UFD	Unión Fenosa Distribución
VTF	Vattenfall
WAC	Wide Area Control
WP	Work Package

1 Purpose of this document

This document provides the details of the final sets of recommendations of the DISCERN project. These conclusions are based on the work and results of the activities performed during DISCERN The project conclusion takes the form of the project summary, how DISCERN has combined the sets of deliverables to contribute to the knowledge base of Smart Grids and their deployment and share this knowledge amongst all industry stakeholders and interested parties.

Readers of this document should also consult the DISCERN final report and the relevant sets of DISCERN deliverables to gain an in-depth understanding of the project, its findings and outcomes. References to the deliverables are provided at the end of this document.

2 Discern recommendations

Based on the developments, analysis and outputs from DISCERN and the full set of deliverables, the partners have identified and developed a set of recommendations to help promote Smart Grid projects. These final recommendations include aspects of technology and economic evaluation to provide realistic support and guidance to industry parties who wish to develop their own sub functionalities. To support knowledge transfer between all parties and further standardisation for Smart Grids, DISCERN has also provided recommendations based on the practical findings of the project. These recommendations have been summarised and categorised for the different sets of industry stakeholders and interested parties, which include:

- Distribution System Operators;
- Vendors and Technology providers;
- Standardization Bodies;
- The European Commission;
- Policy Makers, and
- Research and Development, Scientific Institutions and Consultants.

2.1 Recommendations to Distribution System Operators

I. Leverage the DISCERN Use Case & SGAM approach and tools to support system design and improve internal as well as DSO-Vendor communications.

The Use Case & SGAM approach developed in DISCERN provides a common framework and language that facilitates communications internally within organisations and with external Smart Grid stakeholders. Further, the tools developed within DISCERN support DSOs in engaging with this approach, and in the efficient creation and validation of Use Cases and SGAM representations. DISCERN shows how this approach and associated tools are of benefit to DSOs when designing and procuring Smart Grid systems.

II. To achieve optimal levels of sensor deployment that recognise the capabilities and costs of the technologies as well as the reliability of the communication infrastructure, DISCERN recommends the use of structured system design processes, optimization methods and simulation studies.

Observability of LV/MV networks is a key enabler for development of further Smart Grid functionalities. DSOs therefore wish to deploy sensors, communication technologies and management systems that provide information directly relevant to operational and network planning decisions. DISCERN provides several tools that support DSOs in assessing the appropriate level of sensor deployment. In addition to the DISCERN SGAM and Use Cases tools for easy design Smart Grid architectures and facilitating knowledge sharing, DISCERN has created algorithms for assessing the optimal placement of sensors with respect to cost and accuracy, analysis methods for investigating communication system reliability, and simulation studies on the both impact of RES penetration on the grid and improvements in SAIDI from the deployment of automation and Fault Passage Indicators.

III. Promote internal dissemination activities so as to better understand technical aspects and potential benefits of Smart Grid standards.

The adoption of international standards is key to the future development of the electricity networks, as this will strongly support interoperability and the efficient delivery of solutions. However, taking full advantage of international standards is not an easy task for DSOs. The existence of a large number of standards described in complex technical documents equates to a steep learning curve for DSOs. Furthermore, the standards are developed and maintained by several working groups of experts formed primarily of members from product Vendor organisations, rather than the DSOs themselves. In order to ensure that the standards are well aligned with DSOs' business needs, it is recommended that DSOs promote dissemination within their organisations to provide a good understanding of the technical aspects and potential benefits of communication standards, thereby improving the usability of the standards in the context of electricity distribution networks. To this end, DSOs can take full advantage of the tools and methodologies developed by DISCERN, such as the SGAM-based standards assessment.

IV. Develop standard profiles for communications and standard data models to improve interoperability between information and control systems.

Communication standards and standard data models improve interoperability within information and control systems. Even so, as shown in the detailed analysis performed by DISCERN on the adoption of particular standards in the Smart Grid solutions, the standards are not sufficient in themselves to ensure interoperability. On the contrary, it is recommended that the DSOs take the lead on the specification of companion standards or profiles to extend or possibly restrict the scope of the established standards. In particular, the detailed analysis carried out in DISCERN revealed the need for producing companion profiles for the adoption of the IEC 62056-5-3 DLMS/COSEM, IEC 60870-5-104, and IEC 61850.

V. Leverage the Common Information Model (CIM) as the data model to promote interoperability also in the development of Smart Grid solutions.

The efficient operation of modern distribution networks requires communications and interactions between many diverse systems and functions operated by various actors. It is important, therefore, to use the same terminologies to describe the elements of the power systems, and the same structures to describe the information exchanges between these. By using the CIM, a DSO can specify systems and information formats that can be understood both within and outside the company, allowing devices to be configured for plug-and-play interaction with existing systems.

DISCERN has proposed a novel methodology that provides a structured approach to navigate from the high-level Smart Grid architectures as represented in SGAM models to the definition of specific CIM-based interfaces to be used within the solution. Moreover, DISCERN has developed a semantic model based on the CIM by extending it with new classes to fill the gaps that prevented the representation of certain Smart Grid functions analysed within the project.

VI. Leverage the list of identified key factors that affect the Replicability and Scalability of Smart Grid solutions for future deployment.

In DISCERN, a qualitative analysis of Replicability and Scalability issues has been undertaken for each solution deployed to identify the factors of most relevance for consideration by DSOs looking to implement a solution on a different network area. No single factor makes the Replicability or Scalability of Smart Grid solutions feasible or unfeasible in a different network area as many factors are interconnected. The Validation Checklist concept proposed within DISCERN is considered to be a useful addition to any Scalability and Replicability assessment methodologies that evaluate Smart Grid solutions. The use of this assessment methodology will help to highlight where detailed consideration would be worthwhile to ensure or confirm the feasibility of scaling or replicating the solution in a different network environment.

VII. Investigate and compare Smart Grid solutions and associated benefits at a system-wide level.

To fully analyse and quantify the impact and potential of Smart Grid technologies, one must consider that a “system of investments” is required in order to provide the full spectrum of benefits to the various stakeholders. Within DISCERN, specific technical solutions have been analysed often representing discrete elements or portions of Business Cases, rather than full Business Cases that consider the solution within the wider electricity distribution system. The combination of enabling and operational technologies deployed for Smart Grid solutions and the complementary functionalities that devices could provide are likely to contribute to a number of Use Cases. Thus, DISCERN recommends that the analysis of projects and solutions is extended to include the interactions with other existing and potential future technical solutions. Such an approach will provide the DSO with the ability to fully describe the complete picture and identify the value of Smart Grid solutions.

VIII. Actively participate in the deployment of Smart Grid solutions to increase knowledge and understanding, and to accelerate the maturity of Smart Grid solutions.

DSOs can look to future-proof their networks by gaining early experience with Smart Grid technologies. By trialling Smart Grid technologies on their networks, DSOs gain a direct benefit for their grid / asset strategy together with knowledge and experience to inform further investments. Further, such trials will accelerate the development of the smart technologies such that the market is able to provide mature products that meet the needs of the DSOs and allow the full range of associated benefits to be realised when rolling a Smart Grid solution out across a network area as BaU (Business a Usual).

IX. Discern recommends the application and usage of the SGAM as part of grid planning procedures and tools.

The SGAM framework enables users to create intuitive representations of solutions designed to improve supervision and operation of electricity networks. This framework encompasses and links all the relevant aspects of the solution in a structured manner - from the business needs that are to be addressed to the physical distribution of the devices and applications on the networks - and it is recommended that utilities leverage SGAM to improve the efficiency of the design and procurements

processes for all network enhancement and development projects, particularly those that incorporate communications and data flows to provide smart solutions.

X. The key recommendations from the practical experience gained through the DISCERN demonstration sites include:

- The deployment of Fault Passage Indicators (FPIs) is recommended as these significantly reduce outage times, particularly on long overhead lines, as the fault can be located much more quickly when only a smaller section of the line has to be investigated. The installation of FPIs is straight forward and can often be done without a power outage. To improve the cost efficiency of deployment, where possible FPIs could be installed at the same time as remote controlled disconnectors are installed or exchanged.

- The use of sensors and monitoring devices to provide LV network observability is of great value to DSOs. Devices installed in secondary substations can be used to collect measurements for each phase at feeder level, providing data on load profiles and power quality. This data can be used in its own right or together with data from Smart Meters to provide information for operational decision making and fault identification reducing outage times, and for planning decisions to inform future network investment.

- When designing the communcation infrastructure for Smart Meter deployment, it is important to consider different methods and systems for data gathering so that options are available for deployment in differening network situations. This will allow the solution to be successfully deployed across a network of varying topologies and dispersions of customers, and where intermittant or location specific communication issues are experienced, ensuring that the process of data gathering is as reliable and economically efficient as possible.

- The Advanced Metering Infrastructure deployed at LV network level for Smart Meters can be used to estimate and distinguish between technical and non-technical losses. Loss estimations provide very valuable information on the targeting of loss reduction activities to achieve costs savings, as well as providing a view on the relative proportion of non-technical losses (e.g. theft) in relation to overall system losses.

2.2 Recommendations to Vendors and Technology Providers

I. It is recommended that Vendors take advantage of the DISCERN Use Case & SGAM approach including the Use Case repository in order to better understand the requirements and architectures of the different utilities wishing to develop Smart Grid solutions, and to communicate how their products will deliver the functionality required by the DSO.

The DISCERN Use Case & SGAM approach and tools have been proven to be of benefit for Vendors in efficiently elliciting requirements and presenting solutions.

II. Vendors and DSOs must agree on the goal of a Smart Grid investment

As the new grids evolve it is apparent that implementations of Smart Grid functionalities will differ in different networks, and a solution may need to be tailored for any given network. For this reason, it is recommended that DSOs and Vendors carefully describe the expected outcome, boundary conditions and all other aspects that could impact implementation prior to any decisions being taken. The DISCERN Use Case and SGAM tool box provides an intuitive approach that will ensure a transparent and coherent understanding between all stakeholders, supporting the efficient development and implementation of Smart Grid solutions.

III. DISCERN recommends the use of standards for both communications protocols and information models to ensure interoperability in products being developed.

Many Smart Grid deployments will involve the use of various systems and devices interacting to form a complex system. Products using proprietary information models diminish the efficient operation of modern distribution networks, since they increase the complexity of the communication and interactions between actors. Therefore DSOs look to use interoperable solutions using common standards that allow them to easily take advantage of the information provided by the different systems and devices.

IV. Vendors should consider Replicability and Scalability factors when designing new devices.

Given the extent of distribution networks and the great variety of network topologies, Scalability and Replicability issues have to be considered before deploying a specific Smart Grid solution. A qualitative analysis of these factors has been undertaken within DISCERN and presents the most relevant factors with regard to the DISCERN Use Cases. Further, the framework developed for this analysis is available for use outside DISCERN and can be applied to future projects to guide a comprehensive assessment of the factors important for decision making. As a Vendor, it is important to consider these factors when designing new devices, as these will influence the appeal of products and the possibility of reaching a greater number of potential customers.

V. Develop solutions that improve, rather than replaces, existing system solutions

The development of a Smart Grid solution is about improving a DSO's ability to monitor and control their network. Most DSOs already have some form of support for this. Vendors need to create solutions that will complement and integrate with solutions already deployed, to encourage adoption of the new functionality. The widespread use of standardized protocols will support this design principle.

2.3 Recommendations to Standardization Groups

I. Through the experience gathered during DISCERN, recommendations have made to a number of key standardisation bodies in the electricity and Smart Grid sector to inform improvements to existing standards[1].

Standardisation is a key enabler for the development of future electricity Smart Grids. On the one hand, it is necessary to agree on common methodologies and frameworks for communicating Smart Grid requirements amongst experts from different organisations and areas of expertise, such as electrical engineering, Information and Communication Technologies (ICT), software engineering, or industrial automation. On the other hand, an increasing amount of data has to be processed and exchanged between a number of devices, applications, and systems to implement Smart Grid functionalities that optimize the supervision, control, and management of electricity networks. DISCERN has contributed to standardisation activities with regard to both of these areas. The Use Case & SGAM approach developed and applied within DISCERN to express and analyse requirements and architectures for real solutions designed by large European DSOs enhances existing standard methodologies and frameworks. With regard to the communication standards and canonical data models that facilitate information exchanges within Smart Grid solutions, DISCERN has developed novel methods for undertaking standards assessments related to specific solutions, and has identified recommendations for standardisation actions that will improve the usability of the standards in Smart Grid solutions. Detailed recommendations for standarization bodies can be found at D2.5 "Final report on DISCERN standardisation activities" available at the project website www.discern.eu.

[1] Specific recommendations can be found in the booklet *"Recommendations on standardisation activities"*

2.4 Recommendations to the European Commission

I. A set of well described KPIs (Key Performance Indicators) provides a valuable means for monitoring the performance of individual projects based on a KPI framework, but using KPIs for comparisons between projects can be misleading and should be avoided.

The use of appropriate and well designed KPIs which capture both project context and impacts supports the technical and economic appraisal of projects. It is important to embed the KPIs into project plans from the early design stage, to ensure that the data required is captured and available for analysis.

The use of KPIs to compare projects is generally not valid due to the specific nature of each project in terms of the issues to be addressed by the technical solution, the maturity of the devices and systems used for the solution and the scale of the project. It became apparent within DISCERN that the range of Use Cases deployed varied too widely to fully explore the capabilities of the KPI framework.

II. It is recommended that the DISCERN proposal for the development of a portal to support future documentation of Smart Grid solutions and projects in a structured way is followed up, to allow learning, knowledge and experience to be exchanged between DSOs and other stakeholder.

The development of a portal hosted by an independent party that builds on the tools and methodologies developed within DISCERN will allow information from all Smart Grid FP7 and H2020 projects to be captured and made available to all relevant stakeholders, such as planning and operation experts, ICT & standards specialists, and hardware/software simulation labs. This portal should be based on the Use Case & SGAM methodology, extended to include the KPI framework, to enable DSOs and others to benefit from the experiences and knowledge gained through the implementation of Smart Grid solutions in other projects. The portal would act as a technology knowledge base as well as a documentation repository for individual projects and the results and data obtained, allowing data from both field trials and simulations to be re-used in further projects, and allowing trialled solutions to be reviewed to inform decisions on future Smart Grid projects and proposals.

The DISCERN material and findings set the basis for creating such a web-based project management tool.

III. To enable the reuse of information and experiences from European projects, DISCERN recommends that the EC supports the further development and upkeep of the DISCERN Use Case Management Repository database, including providing a mechanism that encourages and facilitates the use of the DISCERN SGAM and Use Case templates and tools.

For projects involving several demo sites, the EC should also consider advocating the use of the 3L framework to enable structured information sharing.

IV. The scope of Cost Benefit Analysis in Research and Innovation (R&I) projects should be aligned with and adapted to the nature of the R&I being undertaken.

There are boundary conditions that make R&I trial projects very different to those associated with standard deployments (e.g. technical focus vs. business processes focus; based on individual equipment vs. based on integrated solutions; developing new technologies vs. solutions form a competitive market; and knowledge gaining vs. cultural change of an organization). The expected outcomes and applicability of Cost Benefit Analysis (CBA) to assess solutions will be different in each case. The main value of the CBA approach in R&I projects is the identification of cost drivers and sensitivity to these costs, rather than determining specific quantitative values. Cost drivers can be used as a point of reference for moving from a trial project to a logistical, business wide deployment with associated BAU standard processes.

2.5 Recommendations to National Policy Makers

I. DISCERN recommends that specific Regulatory Incentives are developed in relation to innovation, enabling technologies and communications infrastructure, in addition to the traditional CAPEX and OPEX (or TOTEX) price control frameworks, as these are key for supporting deployment of Smart Grid Use Cases.

DISCERN recognises that the wide range of Use Cases that deliver Smart Grid functionalities will bring benefit to the network and its consumers, as well as to the achievement of wider environmental and social policy objectives, however may have different risk profiles when compared to traditional network investments. Regulatory frameworks should develop to recognise these risks and benefits, and thereby promote the extensive roll-out of such technologies and enable network users to gain the substantial benefits in a timely and efficient manner.

II. Common approaches should be developed within regulatory frameworks that enable recognition of "smarter" investments by without leading to technology micromanagement.

As DSOs becomes "smarter", their investment profile will change to include increasing levels of ICT, and generally speaking the average lifetimes of ICT devices are shorter than the average lifetimes of more traditional DSO investments in the electrical infrastructure, e.g. cables. DISCERN therefore recommends that this distinction be made within regulatory frameworks to appropriately reflect the differences (e.g. through faster depreciation, or risk premiums), whilst avoiding technology micromanagement that may limit the benefits to be realised from the use of such technologies.

III. DISCERN recognises that changing energy market structures may impact on the remuneration of DSOs and the funding of their investments, and new regulatory regimes may be required.

When designing the future regulation of distribution grids, it has to be taken into account that customers may have the possibility to choose between different alternatives of energy supply and use models (besides a connection to the electricity distribution network). Further, new market actors may deliver network management and flexibility services to network operators in new and innovative ways. Such developments may require new regulatory frameworks or incentive schemes for the remuneration of DSOs and the compensation of their investments (including new solutions coming from new output based methodologies).

IV. DISCERN has identified that a framework for data-related regulation should be developed and agreed to facilitate the expansion of Smart Grids.

Many of the technologies implemented in DISCERN help to capture and store grid data, including usage patterns and parameters relating to customers. DSOs recognise the need to comply with all relevant data privacy and security regulations, and that updates and adaptations to technologies may be needed through time to ensure compliance and to avoid constraints to the use of any existing technologies. The ongoing or piecemeal development of such regulations could lead to avoidable costs of compliance, and so a framework for data-related regulation should be developed to facilitate the efficient expansion of Smart Grids.

2.6 Recommendations to Scientific Institutions and Consultants

I. It is recommended that Research and Development, Scientific Institutions and Consultants take advantage of a standard, common approach when disseminating results from studies and research projects.

The DISCERN Use Case & SGAM tools were developed to facilitate knowledge sharing between experts from different organisations and fields of expertise. The use of these tools to document and communicate future research projects will facilitate understanding and assessment by DSOs, Vendors and other third parties, and the potential adoption of solutions trialled.

II. The use of benchmark networks that are representative of different kinds of European grids should be encouraged. Furthermore research organisations should provide and maintain an open repository for models of grids and communication systems in accessible software formats for use in further network studies.

The use of benchmark networks both for power grids and communication systems facilitates useful and valid comparison of results, and helps avoid issues relating to confidentiality. An open repository would help to collectively develop a library of benchmark grids that could be easily accessed for use by others in future studies, enabling an easy comparison of outcomes and results to be made.

III. Make use of the Simulation Planning concepts developed within DISCERN to facilitate the communication between DSOs and simulation parties.

A series of proposals related to the inclusion of Simulation Planning concepts (e.g. simulation objectives, scenarios definitions, required inputs and results) within a Semantic Model have been provided within DISCERN, including the incorporation of the DISCERN Semantic Model. A General Diagram model has been proposed to organise the information needed to frame and undertake simulations of any Smart Grid solution, and by using this, the Semantic Model could be structured in a way that includes the relevant information required for associated simulations. The implementation of this methodology would facilitate the sharing of information for and results from simulations between DSOs and simulation experts.

3 Revisions

3.1 Track changes

Name	Date (dd.mm.jjjj)	Version	Changes	
			Subject of change	page
Lutz Itschert	01.12.2015	0,1	Draft version of recommendations	
All	13.01.2016	0.2	Workshop on recommendations	all
Carmen Calpe/ RWE	15.01.2016	1	New version of Recommendations	
Carmen Calpe/ RWE	09.02.2016	1.x	Including comemnts partners	
Lutz Itschert, Alan Birch	01.03.2016	2.0	Drafting deliverable	
Sarah Rigbby	21.03.2016	2.1	Executive summary	
Alan Bircg/DNV GL	23.03.2016	3.0	Final revision	all