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INITIAL REQUIREMENTS FROM RESEARCH COMMUNITIES ANNEX 1.*INAF-CTA*: SELECTED CASE STUDY FROM CHERENKOV TELESCOPE ARRAY ARCHIVE SYSTEM

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Abstract

This report summarizes the findings of T2.1 and T2.2 **for partner Px** along the first three months of the project. It is an integrated document including a general description of the research communities involved and the selected Case Studies proposed, in order to prepare deliverable D2.1, where the requirements captured will be prioritized and grouped by technical areas (Cloud, HPC, Grid, Data management) etc. The report includes an analysis of DMP (Data Management Plans) and data lifecycle documentation aiming to identify synergies and gaps among different communities.

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I. COPYRIGHT NOTICE

II. DELIVERY SLIP

	Name	Partner/Activity	Date
From	Lucio Angelo Antonelli	Px/WP2	
Reviewed by	**Moderators:** P.Solagna, F.Aguilar, J.Marco **Internal Reviewers:** CTA Consortium Board		
Approved by	**PMB**		

III. DOCUMENT LOG

Issue	Date	Comment	Author/Partner
1	5-may-2015	First draft, v01	J.Marco, F.Aguilar CSIC
2	7-may-2015	Initial feedback on structure from all partners	F.Aguilar CSIC, A.Bonvin UUtrecht
3	18-may-2015	Draft discussed in f2f meeting in Lisbon	P.Solagna, EGI.eu F.Aguilar, CSIC
4-7	28-may-2015	Draft ready for initial community input, to be iterated with JRA, v07	P.Solagna, EGI.eu J.Marco, F.Aguilar, CSIC, I.Blanquer UPV
8	4-june-2015	Draft after input from community, v08	JRA?
9	7-june-2015	Draft revised also with JRA, v09	P.Solagna, EGI.eu F.Aguilar, CSIC
10	10-june-2015	Draft to be circulated for internal review, v10	P.Solagna, EGI.eu
11	20-june-2015	Comments included, version for release v11	P.Solagna, EGI.eu

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TABLE OF CONTENTS

0 INTRODUCTION AND CONVENTIONS

PLEASE, READ CAREFULLY BEFORE COMPLETING THE ANNEX:

*This Annex is an example of compilation of the information needed to support adequately a **Case Study** of interest in a Research Community. Each partner in INDIGO WP2 is expected to provide such information along the first three months of the project (i.e. by June 2015), and it will be used to compile Deliverable D2.1 on Initial Requirements from Research Communities.*

There will be around 10 Annexes, for example Annex 1.P1 for partner 1 in WP2 (i.e. UPV), will cover Case Studies from EuroBioImaging research community.

The initial version will be discussed with INDIGO Architectural team to agree on a list of requirements.

Some relevant definitions:

***A Case Study** is an implementation of a research method involving an up-close, in-depth, and detailed examination of a subject of study (the case), as well as its related contextual conditions.*

We should focus on Case Studies that are representative both of the research challenge and complexity but also of the possibilities offered by INDIGO-DataCloud solutions on it!

*The Case Study will be based on a set of User Stories, i.e. how the researcher describes the steps to solve each part of the problem addressed. **User Stories** are the starting point of **Use Cases**, where they are transformed into a description using software engineering terms (like the actors, scenario, preconditions, etc). Use Cases are useful to capture the Requirements that will be handled by the INDIGO software developed in JRA workpackages, and tracked by the Backlog system from the OpenProject tool.*

The User Stories are built by interacting with the users, and a good way is to do it in three steps (CCC): Card, Conversation and Confirmation[1].

Use Cases can benefit from tools like "mock-up" systems where the user can describe virtually the set of actions that implement the User Story (i.e. by clicking or similar on a graphical tool).

Different parts of this document should be completed with the help/input of different people:

RESEARCH MANAGERS

-Section 1, SUMMARY, is to be reviewed/agreed with them as much as possible

RESEARCHERS

*-Section 2, INTRODUCTION is designed to be filled with direct input from (senior) researchers describing the interest of the application, and written in such a way that it can be included in related technical papers. It is likely that such introduction is already available for some communities (for example, for several research communities in WP2 like DARIAH, CTA,EMSO, Structural Biology, one may start from the **Compendium of e-Infrastructure requirements for the digital ERA[2] from EGI***

APPLICATION DEVELOPERS AND INTEGRATORS WITHIN THE RESEARCH COMMUNITIES

-Sections 3, 4, 5, 6: should be discussed from their technical point of view (including data management as much as possible).

MIDDLEWARE DEVELOPERS AND E-INFRASTRUCTURE MANAGERS

-Sections 7, 8: should be discussed with them

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1 For a nice intro, see: https://whyarerequirementssohard.wordpress.com/2013/10/08/when-to-use-user-stories-use-cases-and-ieee-830-part-1/ , and also https://whyarerequirementssohard.wordpress.com/2015/02/12/how-do-we-write-good-user-stories/ etc.

2 *https://documents.egi.eu/public/ShowDocument?docid=2480*

The logical order to fill the sections is: 2,3,4,5,6,1,7,8. Sections 1 and 8 will go into deliverable D2.1.

Other conventions and instructions for this document:

As this document/template is to be reused, the convention to use it as a questionnaire is that:

1) -text in italics provides its structure and questions,

2) -input/content should be written using normal text, replacing **<input here>**

Also the following conventions are used to identify the purpose of some parts of the questionnaire:

Bold text in blue corresponds to indications/suggestions to complete the questionnaire

Bold text in dark red marks technical issues particularly relevant that should be carefully considered for further analysis of requirements

Text in red indicates pending issues or ad-hoc warnings to the reader

1 EXECUTIVE SUMMARY ON THE CASE STUDY

Summarize the research community applications/plans/priorities (max length 2 pages).
To be completed after section 2 and reviewed later. Supervision by a senior researcher is required.

1.1 Identification

- *Community Name*: ***Cherenkov Telescope Array (CTA) Observatory***
- *Institution/partner representing the community in INDIGO:* **CTA Consortium & INAF**
- *Main contact person*: **L. Angelo Antonelli**
- *Contact email:* ***angelo.antonelli@oa-roma.inaf.it***
- *Specific Title for the Case Study:* **Archive System for Cherenkov Telescope Array**

1.2 *Brief description of the Case Study and associated research challenge*

The Cherenkov Telescope Array (CTA) is a large array of Cherenkov telescopes of different sizes and deployed on an unprecedented scale. It will allow significant extension of our current knowledge in high-energy astrophysics.

The CTA observatory will impose a new model to the very-high energy (E>1Tev) gamma ray astronomy data management. The CTA community will create a huge array of ~100 telescopes in two different sites (one in the northern hemisphere one in the southern hemisphere). The CTA will offer worldwide unique opportunities to users with varied scientific interests and support a growing number of young scientists working in the evolving field of gamma-ray astronomy.

The CTA will, for the first time in this field, provide open access via targeted observation proposals and generate large amounts of public data, accessible using Virtual Observatory tools. The CTA aims to become a cornerstone in a networked multi-wavelength, multimessenger exploration of the high-energy non-thermal universe. During the on going preparatory phase of the project, CTA Monte Carlo (MC) simulations campaigns are distributed on the grid via the EGI CTA Virtual Organisation.

Scientific case study

The aims of the CTA can be roughly grouped into three main themes, the key science drivers:

1. understanding the origin of cosmic rays and their role in the Universe;
2. understanding the nature and variety of particle acceleration around black holes;
3. searching for the ultimate nature of matter and physics beyond the Standard Model.

Theme 1 comprises the study of the physics of galactic particle accelerators, such as pulsars and pulsar wind nebulae, supernova remnants, and □-ray binaries. It deals with the impact of the accelerated particles on their environment (via the emission from particle interactions with the interstellar medium and radiation fields), and the cumulative effects seen at various scales, from massive star forming regions to starburst galaxies.

Theme 2 concerns particle acceleration near super-massive black holes. Objects of interest include blazars, radio galaxies and other classes of Active Galactic Nuclei that can potentially be studied in high-energy γ-rays. The fact that CTA will be able to detect a large number of these objects enables the population studies that will be a major step forward in this area. Extragalactic background light (EBL), Galaxy clusters and Gamma Ray Burst (GRB) studies are also connected to this field.

Theme 3 covers what can be called 'new physics', with searches for dark matter through possible annihilation signatures, tests of Lorentz invariance, and any other observational signatures that may challenge our current understanding of fundamental physics.

The CTA will be able to generate significant advances in all these areas.

In particular CTA for the first time will advance the state of the art in gamma ray astronomy in a number of decisive areas:

- For the first time CTA will bring together and combine the experience of virtually all groups world-wide working with atmospheric Cherenkov telescopes.
- CTA aims to provide full-sky view, from a southern and a northern site, with unprecedented sensitivity, spectral coverage, angular and timing resolution, combined with a high degree of flexibility of operation.
- For the first time CTA will operate as a true observatory, open to the entire astrophysics (and particle physics) community, and will provide support for easy access and analysis of data which will be made publicly available and accessible through Virtual Observatory tools.
- The goals of CTA imply significant advances in terms of efficiency of construction and installation, in terms of the technical implementation reliability of the telescopes, in terms of telescopes operations, in terms of data preparation, dissemination and access.

Describe the research/scientific challenge that the community is addressing in the Case Study

The tens of telescopes within the Cherenkov telescope array will produce an unprecedentedly large amount of data (expected >1000PB), thus requiring a challenging architecture of the whole observatory since reliable data processing, data access, their dissemination and transmission are mandatory. The CTA data and their scientific products need to be preserved in a dedicated archive whose aim is to provide open access to a wide and diverse scientific community for several years after the end of the CTA operative life (~30years).

Strictly related to scientific/research challenges are the e-infrastructural challenges; it is possible to summarize the two principal:

1. One of the e-Infrastructure challenges under consideration will consist in defining an adequate computing model for CTA, mainly distributed, and in exploiting the big data

technology with an increased level of complexity added by remote 'wild' experiment sites.

2. The second challenge will be to enable data dissemination to the scientific community through Science Gateway and Single Sign-On solutions for this huge amount of data.

The CTA computing needs are large and expected to grow during the construction and commissioning phase (2016-2020) and the lifetime of the observatory (30 years or more), before they stabilise in the 10 following years.

The CTA Computing Model must be coherent with the aim of an Observatory: to handle a large amount of data generated by the telescopes in remote sites and to provide modern and efficient data access at any level in time, efficiently and at a worldwide scale.

The Computing Model should result from a series of technical solutions suitable for the data pipeline and data reduction constraints as well as for the major user requirements for CTA data management.

The high data rate of CTA together with the large computing power requirements for Monte Carlo simulations need dedicated important computer resources. Another serious functional constraint to the Computing Model is a required Archive System, i.e. a combination of the hardware and associated services for data I/O (in the usual astronomical meaning), for permanent storage of data products that must provide the scientific users with an efficient and organised access to data.

A distributed approach could be more adequate for the scale of CTA. Grid solutions for CTA can be feasible in order to optimize tasks. In 2008 a dedicated CTA Computing Grid (CTACG) project started creating a CTA Virtual Organisation (CTA VO), with the support of the IN2P3-LAPP computing centre and in cooperation with the CC-IN2P3 computing centre. Today the CTA VO is supported by 18 grid sites spread in seven countries, with resources of the order of some thousands of available logical CPUs and more than 600 TB of storage.

Typical MC productions consist of about 150,000 jobs producing about 600 TB of data. In order to handle such massive productions, in 2011 the consortium started the evaluation of the DIRAC (Distributed Infrastructure with Remote Agent Control) system (Arrabito et al., 2012), which is a general framework to manage the distributed activities of a user community. DIRAC has the advantage to integrate heterogeneous resources according to the evolution of the CTA Computing Model.

In parallel with the need to handle data dissemination to the scientific community, another of the CTA challenges is to provide users with a common User Interface: a CTA Science Gateway with complex management of authentication and authorisation mechanisms. The CTA Science Gateway will provide access to resources and services from a distributed computing infrastructure. The resources could be grid computing and storage resources, public and private cloud services, local personal computer resource, user-specific laboratory/institute storage and computing resources, together with CTA observatory storage and computing resources.

For ICT infrastructure, a dedicated CTA Data Management project is working, among other topics, on the proposal of the computing model implementation plan for CTA taking into account the current assumptions on data volumes and processing needs, and including a comparative study about available computing models: centralised, distributed grid, cloud, combined resources, and so on.

1.3 Expectations in the framework of the INDIGO-DataCloud project

What do you think could be your main objectives to be achieved within the INDIGO project in relation to this Case Study?

The size and the world-wide scope of the CTA Consortium, along with the desire of CTAC advanced users to access the full archive and to manage more complex analysis work-flows, demands the implementation of services to operate a common scientific analysis platform. In this respect an important baseline of the IC-infrastructure solution for data access is the CTA Scientific Gateway: a web-based community-specific set of tools, applications, and data collections that are integrated together via a web portal, providing access to resources and services from a distributed computing infrastructure. The Gateway aims at supporting work-flow handling, virtualization of hardware, visualization as well as resource discovery, job execution, access to data collections, and applications and tools for data analysis.

Furthermore the Gateway may even potentially host all monitoring services of data operation as well as some remote control or monitoring applications for instruments and devices when applicable. The continuous and cooperative software development within the CTAC requires some consortium shared services such as a software repository, development tools, version track services and software validation test benches. Most are currently implemented and already in use in CTA, and will evolve in the future into a single web-oriented global platform of services.

Access to the development services, Gateway, and other CTA web resources will be based on each user's profile and category (e.g. basic, advanced users, managers, collaboration users, etc). For such a purpose an Authentication and Authorization infrastructure is under development and will be applied to extend the use of the CTA Gateway to any user (basic or advanced) tuned according to her own role and/or access rights.

The INDIGO infrastructure can help the CTA community to develop and deploy relevant modules needed for the final production CTA. We forsee a dedicated testbed/prototype to be implemented in a distributed environment, possibly cloud-oriented, in order to deploy pilot-projects like "SST-2M ASTRI prototype",[3] and "SST-2M MINIARRAY" projects.[4] These pilot projects will tests all INDIGO solutions related to their data management.

[3] The ASTRI prototype is a single CTA Small Size Cherenkov Telescope with dual mirror technology and Silicon Photo Multiplier detector, it represents a prototype for the CTA and it is an END-to-END project. It is currently in commissioning phase in Sicily, IT.

1.4 Expected results and derived impact

Describe the research results and impact associated to this Case Study.

The main result we expect from the INDIGO collaboration is related to test the performances of the most relevant archive technologies in order to select them and use in the CTA archive.

The impact is mostly related to the multidisciplinary collaboration, with same goals. The work together with scientists having similar problems may help to solve our problems and create a stable testbed for the project development. We have to choose at least several IT-solutions for our project and we hope that INDIGO shared solutions can come to help.

The main goal for CTA collaboration in INDIGO is to overcome current technology limitations, thus improving the user experience in accessing and manipulating this huge amount of CTA data.

1.5 References useful to understand the Case Study

Include previous reports, articles, and also presentations describing the Case Study

-The Cherenkov Telescope Array - Data Management Technical Design Report.

-CTA Consortium (2013) CTA special issue Astroparticle Physics: 43: 1-35

[4] The SST-2M MINIARRAY is the precursor/pre-production project of CTA and it is composed by 9 ASTRI-like telescopes to be located at the CTA South site.

2 INTRODUCTION TO THE RESEARCH CASE STUDY

Summarize the Case Study from the point of view of the researchers (max length 3 pages + table). Input by the research team in the community addressing the Case Study is required.

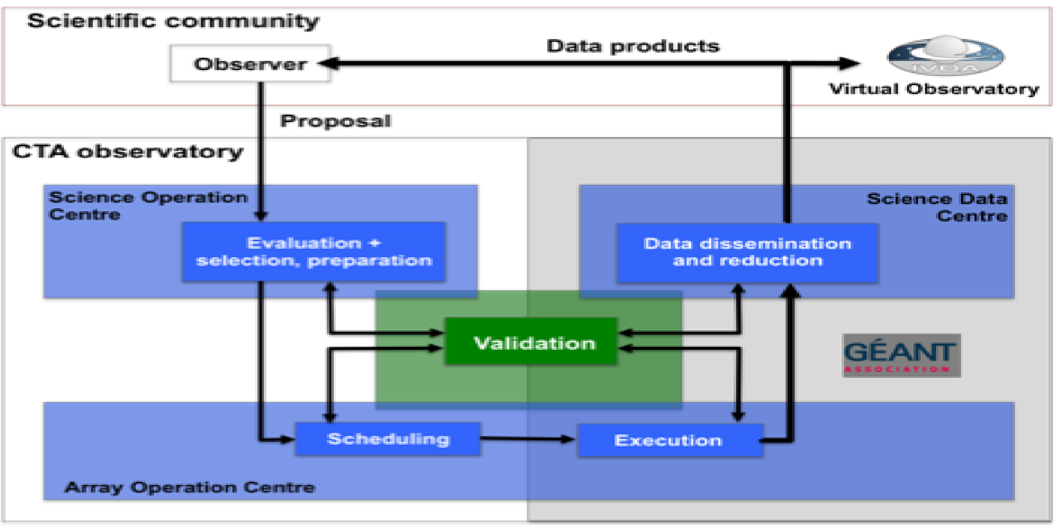
2.1 *Presentation of the Case Study*

Describe the Case Study from the research point of view

VHE gamma-ray astronomy with CTA is evolving towards the model of a public observatory where guest observers will submit observation proposals and have access to the corresponding data, software for scientific analysis and support services. The technical implementation of The CTA Data Management Sub-Project (henceforth referred to as Data Management) therefore fulfills the requirements of a public observatory and aims at guaranteeing reliable processing, ensuring quality of services for access, dissemination and transmission of data.

The CTA data and their scientific products need to be preserved in a dedicated archive guaranteed to provide open access to a wide and diverse scientific community. Data Management provides scientific data products through community-based standards (e.g. the Virtual Observatory) and relies on existing e-infrastructure for data transmission and dissemination.

Handling and archiving the large amount of data generated by the instruments and delivering scientific products according to astrophysical standards is one of the challenges in designing the CTA observatory.



Illu

The workflow in CTA data acquisistion and dissemination is shown in the Illustration n.1. A target is planned to be observed after a Call for proposal time and an evaluation phase.

Several observing plans will be identified and selected to be observed with a particular configuration of the array. These plans will be scheduled and finally observed. Data is automatically reduced and if validated sent back to the Guest observer (i.e. the Principal Investigator who has the responsibility for the proposal submitted) and, after a small time (I.e. one year depending on the observatory policy) the data will become public through the same science gateway and with the Virtual Observatory.

The high data rate of CTA, together with the large computing power requirements for data processing and Monte-Carlo simulations, require dedicated computer resources. Furthermore the participation of scientists from within CTA Consortium and from the greater worldwide scientific community necessitates a sophisticated scientific analysis system capable of providing unified and efficient user access for all data levels, software and computing resources.

The main scope of the project is the design of the CTA Science Data Centre, which is in charge of the off-site handling of data reduction, Monte Carlo simulations, data archiving and data dissemination. The remote (e.g. intercontinental) transmission of data from CTA sites to the CTA archive is one of the key services that the Science Data Centre administers at both ends: off and on the CTA site. The development and provision of software and middle-ware services for dissemination including observation proposal handling is a task that Data Management guarantees to be interfaced with the Operation Centre.

The services and components that the CTA Data Management is in charge of at the CTA sites include: the execution of on-site scientific data reduction pipelines, the real-time analysis software, the on-site temporary archive system as well as the data quality monitoring.

The CTA Archive will handle all the data produced by the Observatory and thus it has to be properly designed in order to reach desired goals. It has to respond to three main issues, which represents projects requirements:

1. the treatment and flow of data from remote telescopes;
2. “big-data” archiving and processing;
3. open access to all data.

The design is inspired by the lessons learned from current and past Atmospheric Cherenkov Telescopes, from existing astronomical observatories, and finally from the technical know-how of major computing and data centres that serve large international projects and world-wide communities.

2.2 Description of the research community including the different roles

Please include a description of the scientific and technical profiles, and detail their institutions

Describe the research community specifically involved in this Case Study

Currently the CTA Consortium organizes the CTA ARCHIVE development activities around five main basic components: (i) data model, (ii) archives, (iii) pipelines, (iv) observer access and (v) IC-infrastructures.

The key members and organizational instances of Data Management are:

- Scientific project coordinator, leading Data Management.
- Project manager, in charge of schedules, plans and documentation.
- A "System team" composed of └ Software architect, assuring the global coherence of all Data Management software products and in interface with ACTL.
- System and Quality Assurance engineers.
- A "Service team" composed of CTA support-group members.
- CTACG technical coordinator.
- Executive board, composed of the leaders of the five main Data Management products, and the management and system teams

Related to the INDIGO project the Archives Sub-WorkPackage of the whole CTA project Data Management organization must be taken into more consideration, since it represents the case study goal of the collaboration within the INGIGO project.

2.3 Current Status and Plan for this Case Study

Please indicate if the Case Study is already implemented or if it is at design phase.

Describe the status of the Case Study and its short/mid term evolution expected

The CTA Archive case study is in the Technical Design Review Phase, but the INDIGO project is related to the software development phase involved in the prototype and pre-production projects of the CTA Archive.

The ASTRI prototype is in realization phase, while the CTA-pre-production miniarray project is still under design since it depends on the CTA realization schedule plan.

2.4 Identification of the KEY Scientific and Technological (S/T) requirements

Please try to identify what are the requirements that could make a difference on this Case Study (thanks to using INDIGO solutions in the future) and that are not solved by now.

Indicate which are the KEY S/T requirements from your point of view

1. Easily handle and manage huge amount of data, thus distribute datacenters and orchestrate services and resources
2. Effective long term storage; thus avoid Silent Corruption: all CTA archives must be free of silent corruption.[5]

[5] Silent corruption in long term storage systems represents a plague is represented by the silent corruption which is the worst type of errors because are unnoticed and so

3. Maximize CAP theorem:

   - Consistency (all nodes see the same data at the same time)
   - Availability (a guarantee that every request receives a response about whether it succeeded or failed)
   - Partition tolerance (the system continues to operate despite arbitrary message loss or failure of part of the system)

   A good DB & Archive System is capable of ensure only two of the three characteristics; in particular**,** Availability "A" (Availability) must be maximized; Partition tolerance "P" must be maximized too, while the Consistency of data "C" must be granted by a good sharding and aggregation technique policy (on geographical storage assembly).

2.5 General description of e-Infrastructure use

Please indicate if the current solution is already using an e-Infrastructure (like GEANT, EGI, PRACE, EUDAT, a Cloud provider, etc.) and if so what middleware is used. If relevant, detail which centres support it and what level of resources are used (in terms of million-hours of CPU, Terabytes of storage, network bandwidth, etc.) from the point of view of the research community.

Detail e-Infrastructure resources being used or planned to be used.

Since 2008 a dedicated CTA Computing Grid (CTACG) was created in order to run simulations. The related CTA Virtual Organisation (CTA VO), support 18 grid sites spread in seven countries, with resources of the order of some thousands of available logical CPUs and more than 600 TB of storage.

To work in production it is recommended to enhance the virtual organisation and spread it over more countries. To gather different services it is also planned to migrate to a cloud environment.

2.6 Description of stakeholders and potential exploitation

Please summarize the potential stakeholders (public, private, international, etc.) and relate them with the exploitation possibilities. Provide also a realistic input to table on KPI.

Describe the exploitation plans related to this Case Study

The most exploitation involved in the use of CTA data which is not related to scientific expectations is related to the use of a common e-Infrastructure at european level in order to efficiently move data in a production phase not only relatetd to a public network but also pubblic. The common use of open standards can help to minimize the learning time for e-science and thus improve the scientific exploitation of CTA data, thus more pubblication, thus more scientific impact factor for the whole project.

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propagated (tests shown that every 15 minutes a silent corruption rise in a long term storage), resulting in cascading failures

Please indicate (as realistic as possible) the expected impact for each topic in the following table:

Area	***Impact Description***	***KPI Values***
Access	*Increased access and usage of e-Infrastructures by scientific communities, simplifying the "embracing" of e-Science.*	• *Number of ESFRI or similar initiatives adopting advanced middleware solutions* ESFRIs: **<input here>** • *Number of production sites supporting the software: 3-5 (in prototyping phase); 10-20 (in production)* • Adoption of open standards to minimize technology learning time.
Usability	*More direct access to state-of-the art resources, reduction of the learning curve. It should include analysis platforms like R-Studio, PROOF, and Octave/Matlab, Mathematica, or Web/Portal workflows like Galaxy.* *Use of virtualized GPU or interconnection (containers).* *Implementation of elastic scheduling on IaaS platforms.*	• *Number of production sites running INDIGO-based solutions to provide virtual access to GPUs or low latency interconnections* **<input here>** • *Number/List of production sites providing support for Cloud elastic scheduling* **<input here>** • *Number of popular applications used by the user communities directly integrated with the project products:* **<input here>** • *Number of research communities using the developed Science Gateway and Mobile Apps:* **<input here>** • *Research Communities external to INDIGO using the software products*: whole CTA
Impact on Policy	*Policy impact depends on the successful generation and dissemination of relevant knowledge that can be used for policy formulation at the EU, or national level.*	• *Number of contributions to roadmaps, discussion papers:* **<input here>**
Visibility	*Visibility of the project among scientists, technology providers and resource managers at high level.*	• *Number of press releases issued*: **<input here>** • *Number of download of software from repository per year:* **<input here>** • *List of potential events/conferences/workshops:* **<input here>** • *Number of domain exhibitions attended* **<input here>** • *Number of communities and stakeholders contacted* **<input here>**
Knowledge Impact	*Knowledge impact creation: The impact on knowledge creation and dissemination of knowledge generated in the project depends on a high level of activity in dissemination to the proper groups.*	• *Number of journal publications:* **<input here>** • *Number of conference papers and presentations*: **<input here>**

Table 1 Key Performance Indicators (KPI) associated to different areas. Add in this table how your community would contribute to the KPIs. Note: this table will NOT be included in the deliverable.

3 TECHNICAL DESCRIPTION OF THE CASE STUDY

Describe the Case Study from the point of view of developers (4 pages max.)
Assemble it using preferably an AGILE scheme based on User Stories.

3.1 Case Study general description assembled from User Stories

Please describe here globally the Case Study. If possible use as input "generic" User Stories built according to the scheme: short-description (that fits in a "card") + longer description (after "conversation" with the research community). Provide links to presentations in different workshops describing the Case Study when available. Include schemes as necessary.

Describe the Case Study showing the different actors and the basic components (data, computing resources, network resources, workflow, etc.). Reference relevant documentation.

It is possible to detect several systems involved in the CTA ARCHIVE workflow (see Illustration n. 2).

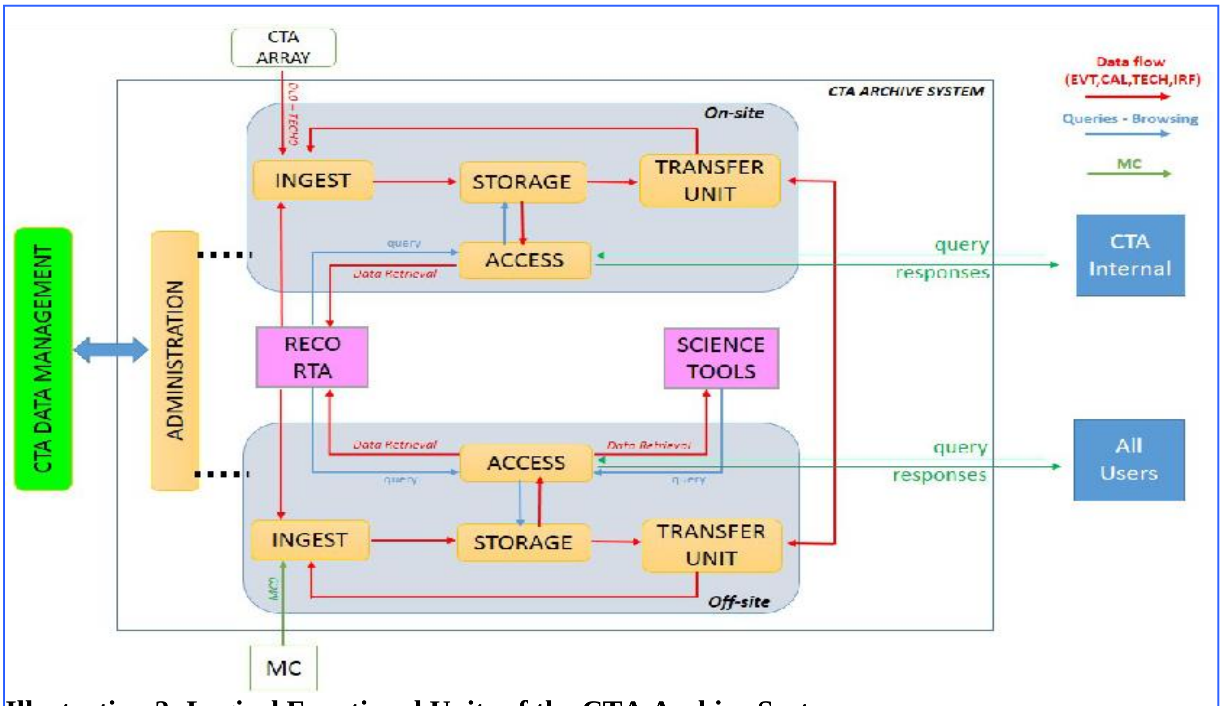

Illustration 2: Logical Functional Units of the CTA Archive System.

The framework unit is also responsible for the definition of the logical structure and architecture of the archive, included internal and external interfaces. The general archive design will involve the implementation of two separate archive units for each array.

The CTA Archive System (CTAAS) architecture and logical design are going to be developed by means of the guidelines and recommendations provided for an Open Archive Information System (OAIS).[6]

- ∟ An on-site archive that represents the front-end CTAAS interface to CTA arrays. It is composed of appropriate repository units that will temporary store raw data files (DL0), the engineering data (TECH) and a set of pre-defined LUT/IRFs (and/or a sub-sample of MC files for their on-site production). The archive will also host the data products expected by the on-site and real-time analysis, including preliminary science products. It will implement management system including databases and access tools for archive browsing by CTA internal users, CTA operators and by the Data Processing Pipelines. It can be considered as one of the node since the whole CTAAS could be federated in a cloud.
- ∟ An off-site archive that will permanently store and make available all the data and observatory products for the scientific community, through dedicated services and databases

The role of data storage unit is to guarantee the efficient retrieval of ingested data, and providing simple archive hierarchy management and maintenance. Storage also supervises the status of the media used in the archive, providing a guarantee of error control and data security. The functions that belong to this unit involve:

- receive data - receives the submission request from the ingest unit and moves data to the appropriate storage within the archive. This function selects the media type, prepares the devices and performs the transfer to the archival volumes.
- hierarchy organization - arranges the archived data following archive structure and administration policy. This function will also provide the appropriate access privileges to the various archive branches according to the CTAO access policy.
- provide data - realizes a copy of the stored data into a temporary buffer area where they can be made accessible to the archive access unit.
- error check - guarantees that data are not corrupted or lost during any CASY-internal data transfer through dedicated error checking mechanisms (e.g., Cyclical Redundancy Check (CRC)). Dedicated error log messages are produced and sent to the archive system administration layer.
- backup - provides mechanisms (according to the administration data policy) for duplicating the archive contents in a physically separated location or by means of distributed resources.

The data access unit consists of a collection of software and on-line services that provide efficient access to the data to the other CTA components (e.g. the data processing pipelines and ACTL). Furthermore, it will make CTA users able to access CTA data accordingly to their specific data access privileges. It will be part of the general Data

6 14Reference Model for an Open Archival Information System - http://public.ccsds.org/publications/archive/650x0m2.pdf

Dissemination Unit (DDU) ensuring the needed support to external archive users (or guest observers) in archive data browsing and retrieval, including the usage of the different archive databases and the release of the science analysis tools for CTA highlevel data visualization and analysis. The following functions are foreseen for the access unit:

- perform query - provides services needed by CTA users and CTA sub-systems to perform scientific and technical queries on the archive content.
- retrieve data - interacts with the storage unit to collect data resulting from a query.
- deliver data - provides on-line and off-line services able to deliver responses and data to users and/or subsystems. It also determines the transmission procedure according to data volume and throughput.
- user support - deals with a range of services (coupled with the Data Access WP) that help CTA users in archive browsing, data and software retrieval.

The data ingest unit involves a collection of software and/or middle-ware able to receive bulk data of different types coming from the array and to prepare them for storage, performing basic operation like data indexing, dependencies and compression. The main functions of ingest are as follows:

└ -receive submission - receive data submitted to the archive by the CTA subsystems. In the onsite archive, the main interface relies on the ACTL/DAQ or event builder subsystems that are in charge of providing data (EVT0 and TECH0) and with level A analysis for data from level 1 up to level 3 (DL1-DL3 data from level A analysis and level B analysis). For the off-site archive, the ingest function will receive data trough the CTA data transfer unit. The function will also provide a confirmation of receipt of the received information.

-generate data description - collects the needed descriptive information from the CTA array subsystems (TECH+AUX) including them as metadata to assure easy data search and retrieval via database.

└ -generate data for the archive - arranges the received data following the archive formatting standards. This may involve merging files/data with external information as well as format conversion, and compression.

The administration unit deals with all the operations related to the CTA archive system and its management. It will assure archive performance and standards/requirements fulfillment by means of dedicated monitoring functionality. Furthermore, it will be in charge of the arrangement of any CASY hardware and software upgrades providing tools to easily handle and recover failures. The foreseen functions belonging to this logical unit are:

-DB admin - manages the different archive databases and their updates

-archive monitor - provides system tools that are able to continuously monitor the functionality of the archive system, checking performances and changes in system configuration.

-archive update - provides mechanisms for updating the contents of the archive

-accounts - creates, maintains, manages, and deletes user accounts

-reports - in charge of periodically creating archive reports with key information related to the status of the archive system to be monitored by the CTA data management.

All Archive Users will access as clients and finally particular operations like Pipeine reconstruction and simulation is expected to be scheduled and executed by a special software framework which manage distributed computing activities and easily queue jobs and dags.

3.2 User categories and roles

Describe in more detail the different user categories in the Case Study and their roles, considering in particular potential issues (on authorization, identification, access, etc.)

The CTA Archive system will serve several kind of users at different levels:

- GUEST_OBSERVER (GO) Guest observers are external CTA users (i.e. researchers, scientists), which are encouraged to submit observation proposals, and will have access to the corresponding data, software for scientific analysis, and support services. This operations are planned to be performed through a dedicated Science Gateway in order to interact with the CTA community
- ARCHIVE USER (AU) Are external users, which access the public archive data through different interfaces. He will take care of archive and database syncronization, mirroring, sharding, replica and backup functions
    - ARCHIVE & CALIB SCIENTIST (AS/CS) are internal users (i.e. Engeneers and DB administrators), whose aim is to supervise the quality and Integrity of the whole CTA data archive
    - SCHEDULER USER (SU) are dedicated users (i.e. CTA staff researchers), which verifies that the ongoing observations fullfill the Guest Observer proposals
    - TIME ALLOCATION COMMETTEE (TAC) are external users (i.e. senior scientists), devoted to grade and rank all observations and proposals to be executed within the Observatory.
- SIMULATIONS & PIPELINE USER (SU/PU) are internal users (i.e. IT specialists on simul, calib and software developers), which will feed the archive of data at different reduction level (Monte Carlo simulated data and real scientific processed data). A privileged access is planned to be implemented. In particular a dedicated software framework to manage distributed computing activities is forseen (a possible candidate is DIRAC = Distributed Infrastructure with Remote Agent Control).

3.3 General description of datasets/information used

List the main datasets and information services used (details will be provided in next section)

The CTA Archive module datasets are organized to physically store all CTA observatory data produced during the data life cycle.

The global CTA Archive SYstem (CASY) storage hierarchy for data reflects the different data levels foreseen for the general CTA data flow. Thus, the contents of the archive will be arranged in order to reflect a logical branch division as follows:

- ∟ Raw Data Archive: is intended to host the raw components of EVT and CAL data stream. Therefore, the raw archive branch will manage EVT0 data produced by event builder as well as the CAL0 data needed by reconstruction pipelines and provided by ACTL. During the first commissioning phase, it will likely store the intermediate data products of the reconstructed pipelines as well.
- Calibration Data Archive: hosts the CAL (> 0) data that are produced at different stages during the data reduction. In particular, this archive will host both CAL1 (single telescope calibration data) and CAL2 (array calibration data). Furthermore, a dedicated sub-branch, will host the master LUT and IRF archive.
- Engineering Data Archive (TECH archive): preserves all housekeeping and auxiliary data as well as slow-control data products provided by ACTL (TECH0, TECH1, TECH3 + AUX).
- MC Data Archive: hosts all the Monte Carlo data simulated for the multiple array stages and observation configurations.
- Science Data Archive: stores the high level data produced by the Data Processing Pipelines (DL3: EVT3, IRF3, and TECH3) that are the primary inputs of the CTA science tools. Controlled access to this archive will be provided to Guest Observers and Archive Users via the data dissemination unit according to the CTA Data Delivery Policy.
- High Level Multi-Frequency Data Archive (VO compliant): hosts official CTA science products like spectra, sky map and light curve (DL4) as well as CTAO products (DL5 - CTA survey and catalogs) that will be accessible under a full multi-wavelength framework. To this end, this archive will be also available under the VO architecture.

3.4 Identification of the different Use Cases and related Services

Identify initial Use Cases based on User Stories, and describe related (central/distributed) Services

1. Guest Observer (GO, i.e. Principal Investigator) will need to browse proprietary data related to a private proposal and after few interactions with a web-based system will retrieve the whole set of data and prepare several higher level outputs to be published in the VO. → The underlying archive will be distributed and data will be sent to the neared storage node according to the GO location in order to minimize latency of further computation and analysis on data. Thus a data retrieval system will grant the peer_to_peer or torrent download on local GO machine.
2. PIPELINE user (PU) will need to access RAW and intermediate data from the archive in order to perform reduction tasks and will store outputs in the archive as higher data levels. → the same distributed archive will handle the authentication of a privileged

user which will run pipelines scripts job on archive/computing cores in the place where data are stored and will prompt the output to the PU user. A scheduler-Job manager will take care of redirect and queue jobs and dag on the proper archive IT-resource.

3. Data Ingestion of each RAW data flow, as well as pipeline intermediate/final data products as well as simulation MC data or just information on P.I. proposals → a dedicated software tool will take care to handle and organize the archive data and meta-data descriptors related to data in a distributed environment and the associated database will be distributed too.

4. Scheduler and TAC users will only need to validate the GO proposals and thus grade and rank them in order to best schedule and queue for observation → this action will mailnly performed through a dedicate web portal access included in the User access section of the CTA Archive.

5. Archive User will take care of best balance archive repositories and database workload in order to optimize all the archive data flow and solve issues → this action can be orchestrated at the Archive, DB and OS Management System, using dedicated tools.

3.5 Description of the Case Study in terms of Workflows

Summarize the different Workflows within the Case Study, and in particular Dataflows. Include the interaction between Services.

On each CTA site, the data rates are based on the event rates from Cherenkov and night-sky-background triggers registered by the telescope array (calculated from Monte-Carlo simulations and site measurements), given a particular trigger scheme.

The rates depend strongly on: the number and type of telescopes in the array, the number of pixels per camera, the nominal trigger rates, the length (in time) of the pixel readout windows, the number of samples per unit time, and the number of bytes recorded per sample.

Some important assumptions are adopted, namely that the full-waveform signal is kept only for selected pixels in a camera while for the other pixels only basic information (e.g. charge integral, time of maximum etc.) is stored.

Some pre-processing and filtering of stereoscopic Cherenkov events will affect the nominal data rates, which will result in 5.14 GB/s for CTA south and 2.58 GB/s from CTA north. They also include 20% calibration data and 10 MB/s of device monitoring and control data for each site, for a resulting total data rate of about 7.8 GB/s.

The exported data are received by the ingestion unit of the CTA Archive system, which is operated (together with all main work-flow management services) by a dedicated Observatory Data Management Centre (CTAO-DMC). The proposed CTAO computing model is built upon a Distributed Computing Infrastructure (DCI) approach, in which a limited number of first-class data-and-computing centres share the workload of archiving and processing the CTA data.

The CTAO-DMC simultaneously guarantees: (i) the orchestration of the relay-mode activities among the four centres, while centrally managing the database of the CTAO archive; (ii) all interface services with the users, providing tools to a dedicated Observatory User Support group and to advanced users for archive queries and data processing or to access technical data for devices monitoring purposes; (iii) the integration of the Scientific Analysis System (SAS) with the CTAO and the CTAC infrastructures, which are also DCIs and are used currently for MC simulation production (through the existing CTA Computing Grid infrastructure - CTACG).

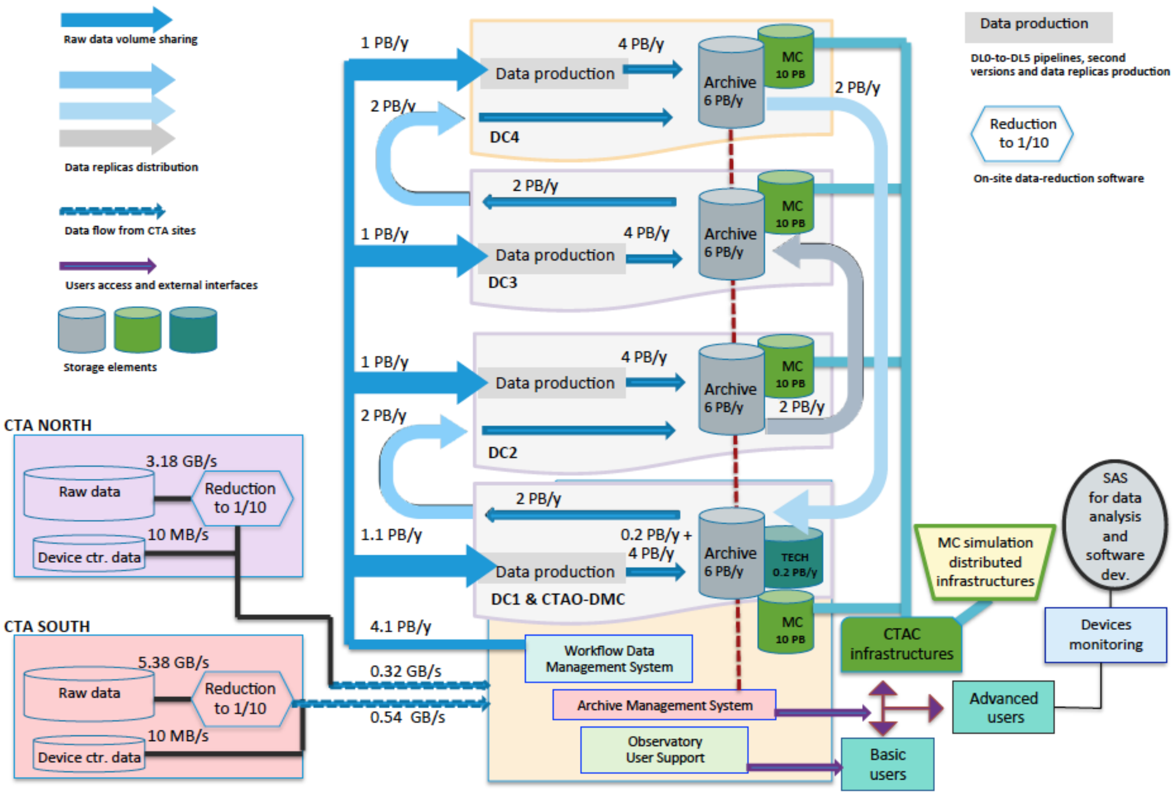

Illustration 3: Raw data and device control data are transferred from CTA sites to the CTAOData Management Centre along the network. Data are then distributed over four datacentres participating in the processingand archive of data. The total data volume, including replicas, is managed by the four datacentres sharing the CTAO storage.

Deliverables of the INDIGO project may help the whole CTA Data Management organization of the Archvie to best develop single logical units and in particular the CTAO-DMC in order to best distribute and manage distributed resources even in CLOUD perspective environment.

3.6 Deployment scenario and relevance of Network/Storage/HTC/HPC

Indicate the current deployment framework (cluster, Grid, Cloud, Supercomputer, public or private) and the relevance for the different Use Cases of the access to those resources.

A punctual deployment framework for CTA Archive is not implemented since the project is in the post TDR phase, where several prototypes are currently been implemented to test different IT-solutions. The INAF activity is mainly concentrated on the ASTRI prototype, and thus related archive and the definition of the pre-production miniarray project.

The CTA archive is planned to be served by a dedicated high-speed network, mainly linked to those developed for LHC experiments. To perform a distributed archive scenario for CTA it is recommended a 10GB/sec point to point connection, already available in the LHC dedicated network. The desired approach should be to re-use feasible yet-developed frameworks in order to grand access and distribute both computing resources both to federate storage (DIRAC resource manager is one example), ACID framework is another.

The ASTRI prototype archive instead is an italian geographical located archive, which will use different solutions to grand access and computational power to a lower data rate. In this contest the INDIGO solutions can come to help to best develop feasible solutions for the pre-production of CTA. To enhance discrete computation, instead to access to super computation power, it is planned to migrate pipelines code to GPUs and equip storage node with a scaled quantity of GPU servers in order to easily handle computation power needed. Tests showed that GPU servers can provide ~10-times the computation power needed to process data with very low power consumption with an averaged costs of hardware of 1/10 of a CPU related server. Tests on Graphical Accelerators performances are still under development and different GPUs architectures are taken into account.

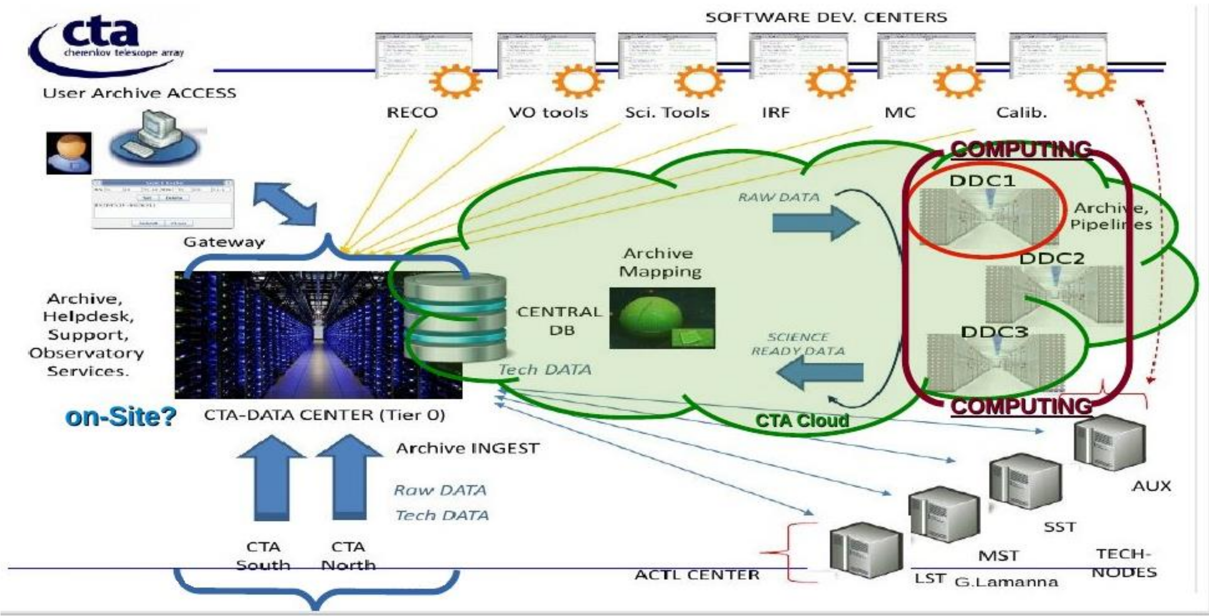

Illustration 4: Proposed scenario for CTA computing model with the INDIGO interaction (cloud and distributed computing).

The whole data archiving and data access functions should also been federated under a dedicated cloud of services, in this the INDIGO defined platforms will come into help.

4 DATA LIFE CYCLE

INDIGO-DataCloud is a DATA oriented project. So the details provided in this complex section are KEY to the project. Please try to be as complete as possible with the relevant information.

Using the DataONE scheme, shown below, the different stages in the data life cycle are considered under the perspective of preparation of a DMP (Data Management Plan) following the recommendations of the UK DCC and H2020 guidelines.

The OAIS data model distinguishes between the storage and the data management logical entities but both belong to the whole CTA Archive System.

- **The RAW DATA Archive (RDA)** is intended to host DL0-DL2 data and will contain also CAL0 data.
- **The Engineering Data Archive (EDA)** will ensure the preservation of all TECH data.
- **The MC Data Archive (MDA)** will contain all the MC productions, IRFs and LUTs produced for the array of telescopes.
- **The Science Data Archive (SDA)** will store DL3 and DL4 scientific data.
- **The High Level Data Archive (HDA)** will make available the Science Archive unde the Virtual Observatory framework, that will pubblish DL4, DL5 and Observatory Products data.
- **The Calibration Data Archive (CDA)** will store CAL(>0) data as well as IRF and LUT produced for the arrays.

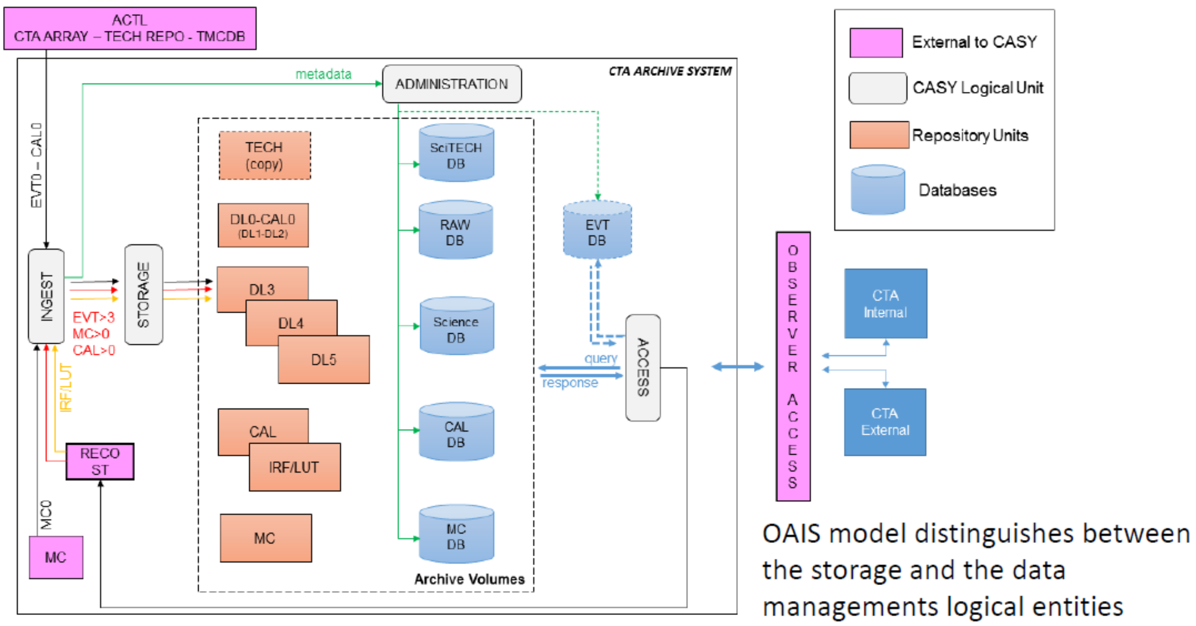

Illustration 5: OAIS model applied to the CTA data Archive System.

To store up all these data it is forseen a set of three different levels of databases, to be developed in strict conjunction with the hardware capability and topology of the Archive.

1. Archive DB, which is the DB that allow users to understand how an observation is performed, i.e. how data (EVT, CAL and MC) are stored, analysed and linked together.
2. The Proposal Handling DB will allow Gos to check the status (acceptance, ranking, …) of the submitted proposal and how their observations are organized, planned and executed.
3. The Technical, Engineering & Monitoring DB that will permit the retrieval of the TECH data describing the status of the CTA array subsystems including real configurations, alerts and auxiliary information.

It was chosen to adopt the Polyglot Persistence to database development, which means that any database resource must be calibrated on the data to be stored and to the use case of users approach. In this scenario different databases may coexists in order to enhance data access and usability od all set of data related to users who need to access them and their use-case.

For the Archive database a non relational approach can came into help and a particular development with the MongoDB which is a document-based DB, was performed.

For the Proposal Handling DB a simple relational database (i.e. MySQL or Postgree) can be enough.

Finally to handle a large amount of simple data of the Technical Engineering and Monitoring DB, a more simple and scalable data model organization can help, so a possible solution was identified in a non relational DB family like a column-store DB (i.e. Cassandra DB).

BEFORE FILLING NEXT SECTIONS, CONSIDER CONSULTING:
https://www.dataone.org/all-best-practices-download-pdf and https://dmponline.dcc.ac.uk/

4.1 Data Management Plan (DMP) for this Case Study

According to EU H2020 indications[7], following UK DCC tool indications

4.1.1 Identification of the DMP

Plan identification: *<Code, ID>* **<input here>**

Associated grants: <Funded Projects, other grants> **<input here>**

Principal Researcher: **<input here>**

DMP Manager: **<input here>**

7 *In Horizon 2020 a limited pilot action on open access to research data will be implemented. Projects participating in the Open Research Data Pilot will be required to develop a Data Management Plan (DMP), in which they will specify what data will be open. Other projects are invited to submit a Data Management Plan if relevant for their planned research. The DMP is not a fixed document; it evolves and gains more precision and substance during the lifespan of the project. The first version of the DMP is expected to be delivered within the first 6 months of the project. More elaborated versions of the DMP can be delivered at later stages of the project. The DMP would need to be updated at least by the mid-term and final review to fine-tune it to the data generated and the uses identified by the consortium since not all data or potential uses are clear from the start. The templates provided for each phase are based on the annexes provided in the Guidelines on Data Management in Horizon 2020 (v.1.0, 11 December 2013).*

Description: **<input here>**

4.1.2 DMP at initial stage (to be prepared before data collection)

The DMP should address the points below on a dataset by dataset basis and should reflect the current status of reflection within the consortium about the data that will be produced.

For each data set provide:

Description of the data that will be generated or collected; indicate its origin (in case it is collected), nature and scale and to whom it could be useful, and whether it underpins a scientific publication. Information on the existence (or not) of similar data and the possibilities for integration and reuse.

Data set reference and name **<input here>**

Data set description **<input here>**

Standards and metadata **<input here>**

SEE TABLE in ILLUSTRATION n. 5 for all data level products and description.

Reference to existing suitable standards of the discipline. If these do not exist, an outline on how and what metadata will be created (see also below).

Connection to Instrumentation,

Sensors, Metadata, Calibration, etc (pending definitive form, see next sections)

<input here>

Vocabularies and Ontologies

Are they relevant? Internal vocabularies related to the specific fields. RDA groups. (pending definitive form, see next sections)

<input here>

Data Capture Methods

Outline how the data will be collected / generated and which community data standards (if any) will be used at this stage. Indicate how the data will be organised during the project, mentioning for example naming conventions, version control and folder structures. Consistent, well-ordered research data will be easier for the research team to find, understand and reuse.

• *How will the data be created?* **By cameras at each telescope focus, by sensors and auxiliary devices**

• *What standards or methodologies will you use?* **Data are produced and stored using astronomical FITS standards and a lot of metadata reflects these standards as well as VO standards.**

• *How will you structure and name your folders and files?* **The archive folder repositories will be organized in this way:**

1) System Archive → representing the physical data repository structured on the basis of the proposal/program and target + arrays keywords

2) Several User Archives, where each user archive is renamed list of logical symbolic links whose organization reflects the optimal way to access data in the particular user-use case.

• *How will you ensure that different versions of a dataset are easily identifiable?* **Using a dedicate DB Management System capable to store data, metadata and versioning of data (i.e. mongo DB Management System is one of these)**

Metadata

Metadata should be created to describe the data and aid discovery. Consider how you will capture this information and where it will be recorded e.g. in a database with links to each item, in a 'readme' text file, in file headers etc. Researchers are strongly encouraged to use community standards to describe and structure data, where these are in place. The UK Data Curation Center offers a catalogue of disciplinary metadata standards.

• *How will you capture / create the metadata?* **Standard parsing/ingestion in the DB and movement in the Archive**

• *Can any of this information be created automatically?* **All informations are created automatically**

• *What metadata standards will you use and why?* **Astronomical FITS standards and VO compliant standards in order to produce VO compatible data ready to be pubblished on VO servers.**

Data sharing

Description of how data will be shared, including access procedures, embargo periods (if any), outlines of technical mechanisms for dissemination and necessary software and other tools for enabling re-use, and definition of whether access will be widely open or restricted to specific groups. Identification of the repository where data will be stored, if already existing and identified, indicating in particular the type of repository (institutional, standard repository for the discipline, etc.). In case the dataset cannot be shared, the reasons for this should be mentioned (e.g. ethical, rules of personal data, intellectual property, commercial, privacy-related, security-related).

Depending on the data policy, after 1 year all proprietary data will become pubblic, so it will be available through the data access service also to not P.I. users. After this automatic publication it will be possible to publish higher level products to the Virtual Observatory servers in order to be directly usable by all VO tools available to the astronomical community.

Method for Data Sharing

Consider where, how, and to whom the data should be made available. Will you share data via a data repository, handle data requests directly or use another mechanism? The methods used to share data will be dependent on a number of factors such as the type, size, complexity and sensitivity of data. Mention earlier examples to show a track record of effective data sharing.

• *How will you make the data available to others?* **Automatic publishing: each proprietary data will have a countdown time bofore that it will become pubblich and all higher level products related will be published in the VO.**

• *With whom will you share the data, and under what conditions?* **Also for public data the CTA consortium will ensure a data policy on usage, ut it is still under debate.**

Restrictions on Sharing

Outline any expected difficulties in data sharing, along with causes and possible measures to overcome these. Restrictions to data sharing may be due to participant confidentiality, consent agreements or IPR. Strategies to limit restrictions may include: anonymising or aggregating data; gaining participant consent for data sharing; gaining copyright permissions; and agreeing a limited embargo period.

• *Are any restrictions on data sharing required? e.g. limits on who can use the data, when and for what purpose.* **Only a proprietary time restriction**

• *What restrictions are needed and why?* **<input here>**

• *What action will you take to overcome or minimise restrictions?* **<input here>**

Data Repository

Most research funders recommend the use of established data repositories, community databases and related initiatives to aid data preservation, sharing and reuse. An international list of data repositories is available via Databib or Re3data.

• *Where (i.e. in which repository) will the data be deposited?* **All suitable data to be accessed pass through the CTA Archive, except a small set of metadata related to proposals.**

Archiving and preservation (including storage and backup)

Questions to consider before answering:

•What is the long-term preservation plan for the dataset? e.g. deposit in a data repository

•Will additional resources be needed to prepare data for deposit or meet charges from data repositories?

Researchers should consider how datasets that have long-term value will be preserved and curated beyond the lifetime of the grant. Also outline the plans for preparing and documenting data for sharing and archiving. If you do not propose to use an established repository, the data management plan should demonstrate that resources and systems will be in place to enable the data to be curated effectively beyond the lifetime of the grant.

• What additional resources are needed to deliver your plan?

• Is additional specialist expertise (or training for existing staff) required?

• Do you have sufficient storage and equipment or do you need to cost in more?

• Will charges be applied by data repositories?

• Have you costed in time and effort to prepare the data for sharing / preservation?

Carefully consider any resources needed to deliver the plan. Where dedicated resources are needed, these should be outlined and justified. Outline any relevant technical expertise, support and training that is likely to be required and how it will be acquired. Provide details and justification for any hardware or software which will be purchased or additional storage and backup costs that may be charged by IT services. Funding should be included to cover any charges applied by data repositories, for example to handle data of exceptional size or complexity. Also remember to cost in time and effort to prepare data for deposit and ensure it is adequately documented to enable reuse. If you are not depositing in a data repository, ensure you have appropriate resources and systems in place to share and preserve the data.

Describe the procedures that will be put in place for long-term preservation of the data.

The whole CTA Archive is designed to be fully NO SPOF, the distribute architecture will ensure all this characteristic, but a backup policy of more relevant data-set will be taken into account.

The Replica set- sharded archives will optimize the production environment and grant the possibility to expand horizontally all the dataset in different data centers, without affecting the operations and the performances of the whole archive.

Indicate how long the data should be preserved, what is its approximated end volume, what the associated costs are and how these are planned to be covered. **Data must be preserved forever! (at least 30 years after nominal CTA operations)**

4.1.3 DMP at final stage (to be ready when data is available)

SCIENTIFIC RESEARCH DATA SHOULD BE EASILY ***DISCOVERABLE***

Questions to consider:

• How will potential users find out about your data? Query to a file/service catalog

• Will you provide metadata online to aid discovery and reuse? Yes sure

Guidance: Indicate how potential new users can find out about your data and identify whether they could be suitable for their research purposes. For example, you may provide basic discovery metadata online (i.e. the title, author, subjects, keywords and publisher).

Are the data and associated software produced and/or used in the project discoverable (and readily located), identifiable by means of a standard identification mechanism (e.g. ***Digital Object Identifier****)?* **The complexity of astronomical data is difficoult to be addressed by a an Object Identified but it is possible to tune-up the searchable keywords for VO research in order to create an ad hoc Astronomical Object Identifier.**

SCIENTIFIC RESEARCH DATA SHOULD BE **ACCESIBLE**

Questions to consider:

• Who owns the data? The observatory and the proprietary P.I. for a short period of time.

• How will the data be licensed for reuse? TBD

• If you are using third-party data, how do the permissions you have been granted affect licensing? If a user has permission on a data set no restriction will be addressed.

• Will data sharing be postponed / restricted e.g. to seek patents? TBD

State who will own the copyright and IPR of any new data that you will generate. For multi-partner projects, IPR ownership may be worth covering in a consortium agreement. If purchasing or reusing existing data sources, consider how the permissions granted to you affect licensing decisions. Outline any restrictions needed on data sharing e.g. to protect proprietary or patentable data. See the DCC guide: How to license research data.

Are the data and associated software produced and/or used in the project accessible and in what modalities, scope, licenses? (e.g. licencing framework for research and education, embargo periods, commercial exploitation, etc) ***See aswers inline.***

SCIENTIFIC RESEARCH DATA SHOULD BE ***ASSESSABLE*** *AND INTELLIGIBLE*

• What metadata, documentation or other supporting material should accompany the data for it to be interpreted correctly?

• What information needs to be retained to enable the data to be read and interpreted in the future?

Describe the types of documentation that will accompany the data to provide secondary users with any necessary details to prevent misuse, misinterpretation or confusion. This may include information on the methodology used to collect the data, analytical and procedural information, definitions of variables, units of measurement, any assumptions made, the format and file type of the data.

Are the data and associated software produced and/or used in the project assessable for and intelligible to third parties in contexts such as scientific scrutiny and peer review?, e.g. are the minimal datasets handled together with scientific papers for the purpose of peer review, are data is provided in a way that judgments can be made about their reliability and the competence of those who created them.

Astronomical data are usually coherent for compatibility reasons, so a very large set of metadata are identified to be easily inter-operable between instruments, telescopes and missions. A lot of metadata are human-readable so that using the standard FITS format any users can parse the initial part of an Astronomical data inspecting its header and understand descriptors.

***USABLE** BEYOND THE ORIGINAL PURPOSE FOR WHICH IT WAS COLLECTED*

• What is the long-term preservation plan for the dataset? e.g. deposit in a data repository

• Will additional resources be needed to prepare data for deposit or meet charges from data repositories?

Researchers should consider how datasets that have long-term value will be preserved and curated beyond the lifetime of the grant. Also outline the plans for preparing and documenting data for sharing and archiving. If you do not propose to use an established repository, the data management plan should demonstrate that resources and systems will be in place to enable the data to be curated effectively beyond the lifetime of the grant.

Guidance on Metadata:

• How will you capture / create the metadata?

• Can any of this information be created automatically?

• What metadata standards will you use and why?

Metadata should be created to describe the data and aid discovery. Consider how you will capture this information and where it will be recorded e.g. in a database with links to each item, in a 'readme' text file, in file headers etc.

Researchers are strongly encouraged to use community standards to describe and structure data, where these are in place. The DCC offers a catalogue of disciplinary metadata standards.

Are the data and associated software produced and/or used in the project useable by third parties even long time after the collection of the data? e.g. is the data safely stored in certified repositories for long term preservation and curation; is it stored together with the minimum software, metadata and documentation to make it useful; is the data useful for the wider public needs and usable for the likely purposes of non-specialists?

Several astronomical data are usually used for other scientific fields. The definition of intellegible metadata is usually devoted to the instrument responsible of data acquisition (i.e. a spectrometer or just a pixel camera). The data flow can be redirected and buffered for storage and once it is opportunely and properly reduced it become "science ready" and can be stored for

long term to a pubblic archive. ***The public archive may serve for multi-wavelength campaign and multi-disciplinary researches.***

INTEROPERABLE *TO SPECIFIC QUALITY* ***STANDARDS***

• What format will your data be in? **FITS format as well**

• Why have you chosen to use particular formats? **Interoperability between mission and long term archival for astronomical datasets.**

• Do the chosen formats and software enable sharing and long-term validity of data? **YES**

Outline and justify your choice of format e.g. SPSS, Open Document Format, tab-delimited format, MS Excel. Decisions may be based on staff expertise, a preference for open formats, the standards accepted by data centres or widespread usage within a given community. Using standardised and interchangeable or open lossless data formats ensures the long-term usability of data?

See the UKDS Guidance on recommended formats

Are the data and associated software produced and/or used in the project interoperable allowing data exchange between researchers, institutions, organisations, countries, etc?, e.g. adhering to standards for data annotation, data exchange, compliant with available software applications, and allowing re-combinations with different datasets from different origins

All piece of software developed and used to manage, store and handle data respond to international astronomical fits standard. Also different mission/instruments can be translated to become compatible with fits standard.

4.2 Data Levels, Data Acquisition, Data Curation, Data Ingestion

4.2.1 General description of data levels

Indicate if the DATASETS are organized into different levels (LEVEL-0, 1, 2, 3,4) and if so what are the relevant definitions and how DOI are provided.

DATA (EVT)	SHORT NAME	DESCRIPTION	ARCHIVE BRANCH
Level 0 (DL0)	RAW	Data from DAQ written to disk	RDA
Level 1 (DL1)	CALIBRATED	Physical quantities measured in the camera: photons, arrival times etc.	RDA
Level 2 (DL2)	RECONSTRUCTED	Reconstructed shower parameters (energy, direction, particle ID	RDA
Level 3 (DL3)	REDUCED	Set of selected (e.g., gamma-ray) events	SDA
Level 4 (DL4)	SCIENCE	High level data products (spectra, skymaps, lightcurves)	SDA
Level 5 (DL5)	OBSERVATORY	Final products of the Observatory such as CTA survey sky maps or source catalog.	HDA (VO-compliant)
CAL/IRF/LUT	CALIBRATION	Calibration data & IRF/LUT	RDA & CDA
MC	MONTE CARLO	Monte Carlo productions for data analysis	MCA
TECH	ENGINEERING	Slow-control, housekeeping and auxiliary data (formerly ENG,AUX)	EDA

Illustration 6: ASTRI/CTAO data levels specifications

The table in illustration n.6 represents the different branches of data involved in CTA archive their levels and related databases involved in the storage.

4.2.2 Collection/Acquisition

Gathering RAW data

Specify how do you gather/collect your data (e.g. sensors, observations, satellites, etc.)? ***Sensors (I.e. cameras) + House-keeping and Auxiliary devices***

How do you pre-process, transfer and store your RAW data?

Data Acquisition, Ingestion, Storage, Pipeline Analysis and Validation are different atomic processed sometimes involved at different times during the life-cycle of data in the Archive System

From RAW Data to Calibrated Data

Describe the processes applied for Data Calibration, Validation, Filtering, etc. **<input here>**

4.2.3 Access to external data

Describe the identification and access to External Data **<input here>**

Indicate if there is a procedure for validation of External Data **<input here>**

4.2.4 Data curation

Specify any automatic check applied, like completing series, detecting outlier

The data check in cherenkov data is performed identifying good time intervals (GTI): data within GTI aregood for astronomical observations and can be used for science.

Describe manual quality checks **In case of problems can be run several check by engineers.**

Are there quality flags applied to the data? **Yes automatic pipelines are used.**

4.2.5 Data ingestion / integration

Describe transformations applied to data taking into account ontologies/metadata. Indicate also if there is any "harmonization procedure" (to share/integrate data) and how linking internal and external data is made if relevant.

Starting from proprietary RAW data the first operation is to convert it in a FITS file format with a header of astronomical descriptors and a binary part of files with fits-table or image. Then the image is calibrated, reconstructed and linked together to other image events in order to reconstruct the behaviour of the event and discriminate from spurious signals (i.e. cosmic rays) and real gamma ray photons. Then the spectral energy is computed and the final products of photon list associated to the data taken is stored. All analysis step produce

different levels of data to be stored in the archive as well as the information on the operation performed on them.

4.2.6 Further data processing

Describe, if relevant, the different additional processing steps (and the associated software and resources) applied to the (collected/curated) datasets to provide a "final" dataset collection that can be used in the analysis

These tasks are mainly observatory higher level products by P.I. responsibility.

4.3 Analysis

4.3.1 Basic analysis and standard analysis suites

Describe usual examples of basic analysis in the Case Study **<input here>**

Specify if software packages/tools like MATLAB, R-Studio, iPython,etc. are used

There are several pipeline alghoritms well suited for gamma ray astronomy and cherenkov images in particular. These program, mainly written in C/C++ have to be adapted at the special instrument configuration and the observatory site.

For the GPU programming language CUDA is currently used.

Doxygen for documentation, GIT and SVN for versioning, SCONS and SONAR for code profiling and optimization.

4.3.2 Data analytics and Big Data

Describe relevant examples of advanced analysis in the Case Study (like for example application of neural networks, series analysis, etc.)

Possible production of event list dispatcher (Event Pruner) can identify searchs among billions of records and perform analytics on data-set results in order to produce aggregated informations.

Specify the resources and additional software required

Dedicated HPC Computations and NOSQL databases supporting in-line analytics (like hadoop or SciDB)

Identify analysis challenges that can be classified as "Big Data"

Billions of DB records (photon list) to be graded, linked together and searchable in a human compatible time, statistics and aggregation on different attributes, like energy, position or other high level descriptor like proposal/program, target (i.e. RA, DEC) or DATE_OBS.

List Big Data driven workflows **<input here>**

4.3.3 Data visualization and interactive analysis

Indicate the need for data and analysis results visualization

Only a browsing system is needed in order to navigate in the metadata.

Indicate how visualization is made and if interactivity/steering is needed **<input here>**
Specify the User Interfaces (web, desktop, mobile, etc.)
Mainly a web portal is needed to provide different user access at different levels, plus a REST API for application direct connection.

4.4 Data Publication

Describe the information flow from the analysis to the publication **<input here>**
RAW Data are produced, pas through a pipeline calibration analysis which generates higher level products. These products are stored within the archive and are accessible through a dedicated web gateway to PI users; after a small time (i.e. one year) data become public and can be published in the VO with open data access.
Indicate the requirements from publishers/editors to access data, and how it is made available (open data?)

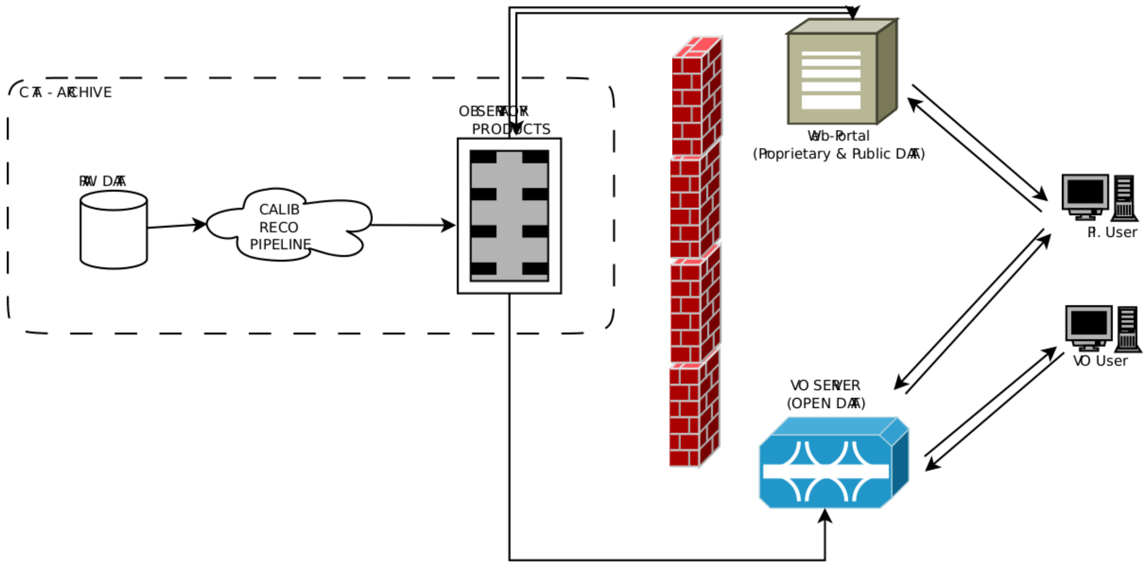

Illustration 7: The simple schema for data publication in CTA.

5 SIMULATION/MODELLING

Describe the Simulation/Modelling requirements in this Case Study. Please identify also any other intensive CPU mainly activity as required.

Pipeline and simulation tasks are carried on different Work packages respect to the archive system, which is only responsible to store the data produced by any simulation and data handling process.

5.1 General description of simulation/modelling needs

Describe the different models used (including references) **<input here>**

*Indicate the type and quantity of simulations needed in the Case Study, and how they are incorporated in the general workflow of the solution***<input here>**

5.2 Technical description of simulation/modelling software

For each simulation package:

Identify the simulation software: **different proprietary modules written in C/C++ Python Java and related API**

Provide a link to its documentation, and describe its maturity and support level **in development and beta testing**

Indicate the requirements of the simulation software (hardware: RAM, processor/cores, extended instruction set, additional software and libraries, etc.)

CPUs ~ 2000 cores (or ~ 10-20GPUs)

RAM 4-8GB per core/threa*d*

Tag the simulation software as HTC or HPC **HTC: keep constant data pressure!**

List the input files required for execution and how to access them **total >10PB (~>1PB/year)**

Describe the output files and how they will be stored **total >100PB (~>10PB /year) with 0.5PB temporary storage. It is an incremental storage since it depends on the number of telescope simultaneously operating at the array (from 0.3 to 3TB/night each); Medium data size involved ~5TB/night with final products ~0.5TB/night.**

The principal kind of data is the astronomical FITS file format, ROOT, RAW, DB products like JSON, BSON & XML.

Reference an existing installation and performance indicators **<input here>**

Specify if the simulation software is parallelized (or could be adapted)

Yes, the kind of parallelization is the embarassing parallelization where single jobs are run independently to different resources. Highly granular.

Specify if the simulation software can exploit GPUs

Yes it is under development

Specify how the simulation software exploits multicore systems

It will use totally independent jobs with no connection together in order to maximize the throughput of use different multi-threads architectures.

Specify if parametric runs are required

Not necessarily.

Estimate the use required of the resources (million-hours, # cores in parallel, job duration, etc)

Depending on the archive topology and the aggregation degree: coherent data near the computing in the data-center (no need to move files => no connectivity needed); if the data is far from computing or is not coherent it needs to be moved so a good connectivity od 10GB/s.

Virtualize resources for computing near the location of data and near users who requires them-> aggregate data in the same place to process and limit the file movements.

It is expected a coarse grain workflow distribution, since the real advantage of the parallelization can be reached in a ebarassing paralelization of jobs not coupled.

5.3 Simulation Workflows

Describe if there are workflows combining several (HTC/HPC) simulations or simulations and data processing

TBD

6 DETAILED USE CASES FOR RELEVANT USER STORIES

This section tries to put the focus on the preparation of detailed Use Cases starting from User Stories most relevant to the Case Study considered.

6.1 Identification of relevant User Stories

Examples of relevant User Stories linked to roles like for example Final User, Data Curator, etc.

List User Stories based on data collection, curation, processing, analysis, simulation, etc, that are considered most relevant for the Case Study being analyzed **<input here>**

For each relevant User Story:

Draft a basic card **<input here>**

Provide details from conversation with the researchers' teams **<input here>**

Draft as a Use Case **<input here>**

Analyze tools to support the definition of the Use Case (like mockups). Integrate in the analysis the requirements on user interfaces (like the use of mobile resources, under different flavours, access through web interfaces, etc.) **<input here>**

Describe the way to extract requirements and define acceptance criteria **<input here>**

Include if possible an example of support for Big Data driven workflows for e-Science, with requirements for scientific workflows management, under a "Workflow as a Service" model, where the proper workflow engines will be selected according to user needs and requirements.

In such case please describe the scenario for Big Data analysis, and assure that the Use Case considers which levels of workflow engines are needed (e.g., "coarse gran", which targeting distributed (loosely coupled) experiments, through workflow orchestration across heterogeneous set of services; "fine grain", which targeting high performance (tightly coupled) data analysis through workflows orchestration on big data analytics frameworks)

7 INFRASTRUCTURE TECHNICAL REQUIREMENTS

Describe the Case Study from the point of view of the required e-infrastructure support. INDIGO Data-Cloud will support the use of heterogeneous resources.

7.1 Current e-Infrastructures Resources

Start from the current use of e-infrastructures.

The first ASTRI archive prototype is going was installed at the Osservatorio Astronomico di Roma

7.1.1 Networking

Describe the current connectivity **A single storage node not well connected.**

Describe the key requirements (availability, bandwidth, latency, privacy, etc)

The archive system should be distributed highly available and averaged well connected without bottlenecks.

Specify any current issue (like last mile, or access from commercial, etc)

Current connectivity bottleneck and electrical power continuity not performant (SPOF)

7.1.2 Computing: Clusters, Grid, Cloud, Supercomputing resources

Describe the current use of each of these type of resources: size and usage

NO GRID- NO CLOUD – NO superconputing resources (only NVIDIA TESLA K20 GPUs and a multicore machine up to 64 cores+hiperthreads and 512GB ram).

Indicate if there is any mode of "orchestration" between them

NO

7.1.3 Storage

Describe the current resources used

Few Centralized storage redundant NAS (~200TB) for archive testing functionalities.

Discuss the key requirements (I/O performance, capacity, availability, reliability, any other QoS indicator)

It is planned to migrate in a storage cloud platform using open solutions like Eucalyptus (www.eucalyptus.com)

7.2 Short-Midterm Plans regarding e-Infrastructure use

Plans for next year (2016) and in 5 years (2020).

At least three different storage nodes well connected and orchestrated through the GARR 10GB/s lan.

7.2.1 Networking

Describe the proposed connectivity

INFN GARR 10GB/s point to point LAN

Describe new/old key requirements (availability, bandwidth, latency, QoS, private networking, etc)

Each node will be in a private network (mainly infiniband connection) to minimize the access time latency and enhance throughput from the storage to the computing.

Specify any potential solution/technique (for example SDN)

TBC

7.2.2 Computing: Clusters, Grid, Cloud, Supercomputing resources

Describe the evolution expected: which infrastructures, total "size" and usage **<input here>**

Detail potential "orchestration" solutions

Automatic manage balancing. The fail of a node will result in a secondary node election to primary, a set of warning and notification to human intervention to recovery the failed node.

No particular requirement only an active network balance for the job execution in the cloud and the amount of data to single nodes avoiding bottlenecks.

In CTA it is currently used DIRAC for simulations. In a distributed archive scenario computing resources follows the stored data but they are managed allocated and orchestrated by a top-supervisor in order to best balance the data jobs and workflows execution.

7.2.3 Storage

Describe the resources required

~3 sites with 2 racks each "full of disks" with capacity depending on the storage technology: if used 8TB disks ~5PB each → at pre-production regime 30 redundant PB distributed on three sites.

Discuss the key requirements (I/O performance, capacity, availability, reliability, any other QoS indicator)

CTA will store about ~24TB/Night (I.e. ~10PB/Year), thus 10 PB per year including calibs, reduction and MC simulation data. Depending on the trigger rate, the size of each event the scenario can be more pessimistic (>100PB/year to be addressed). The CTA Archive system must store, manage, preserve and provide easy access (IVOA Access) to a such huge amount of data for a long time.

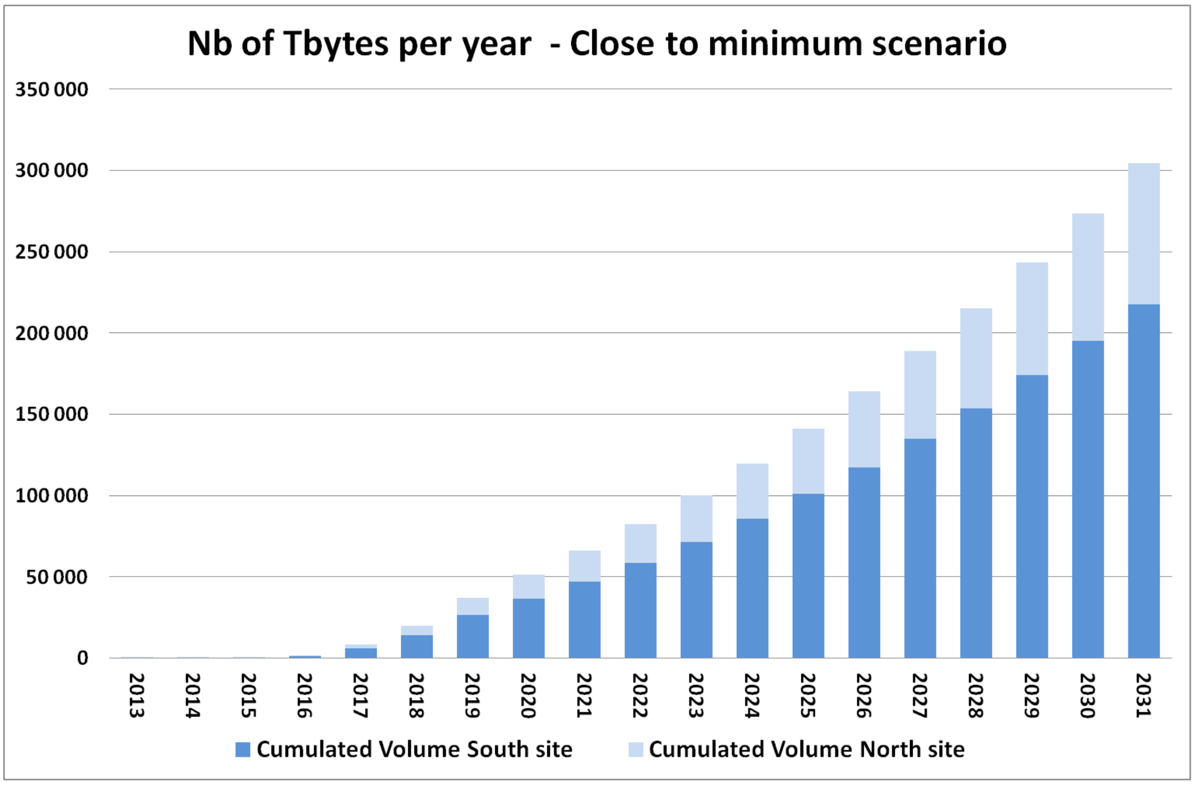

Illustration 8: Predicted cumulative data stored by CTA.

7.2.4 SPECIFIC QUESTIONS REGARDING USE OF EGI.eu (FROM EGI DOC 2478)

Sample questions to capture details of a support case

These questions can help case supporters interview the case submitter and the NGIs to refine the technical details of the case and ultimately to move towards a suitable technical setup. These questions aim at understanding the user's need, the technical and other requirements/constrains of the case, and the impact that a solution would bring to the scientific community. These questions provide only guidance – Ticket owners can use other questions or even other methods to identify details of their support case(s).

- *What does the user/community want to achieve? (What's the user story?)*
- *For who does the case request resources for? (CPU/storage capacity, SW tools, consultant time, etc.) For a group? For a project? For a collaboration? Etc.*
- *What is the size of the group that would benefit from these resources, and where these people are? (which country, institute)*
- *Approximately how much compute and storage capacity and for how long time is needed? (may be irrelevant if the activity is for example assessment of an EGI technology)*

- *Does the user need access to an existing allocation (→ join existing VO), or does he/she needs a new allocation? (→ create a new VO)*
- *What is the scientific discipline?*
- *Which institute does the contact work for (or those he/she represents)?*
- *Does the case include preferences on specific tools and technologies to use?*
    - *For example: grid access to HTC clusters with gLite; Cloud access to OpenStack sites; Access to clusters via standard interdafaces; Access to image analysis tools via Web portal*
- *Does the user have preferences on specific resource providers? (e.g. in certain countries, regions or sites)*
- *Does the user (or those he/she represents) have access to a Certification Authority? (to obtain an EGI certificate)*
- *Does the user (or those he/she represent) have the resources, time and skills to manage an EGI VO?*
- *Which NGIs are interested in supporting this case? (Question to the NGIs)*

7.3 *On Monitoring (and Accounting)*

Please outline any requirements for monitoring of the platforms and the applications.

If you have specific tools already in use, please outline them.

Please also specify monitoring, metrics at different levels: system, performance, availability, network QoS, website, security, etc.

The software delegated to federate the storage cloud must be capable to collect system informations to best balance workloads and distribute computations and storage driven by user requests and availability of resources.

7.4 *On AAI*

(From EGI, revise and check with WP4/5/6)

Describe the current AAI status of your community/research infrastructure

• Does your community/research infrastructure already use AAI solutions? **<input here>**

• Can you describe the solutions you have adopted highlighting as applicable: Technology adopted (e.g. X509, SAML Shibboleth,...), Identity Providers (IdP) federations integrated (e.g. eduGAIN) or approximate number of individual IdPs integrated, Solution for homeless users (users without an insitutional IdP), Solutions to handle user attributes **<input here>**

Describe the potential needs and expectations from an AAI integration in the ***services and platforms provided by INDIGO***

- *Type of IdP to be integrated (e.g. institutional IdP part of national federations and eduGAIN or non federated, social media credentials, dedicated research community catch-all IdP, ...)* **<input here>**
- *Preferred authentication technology, and requirements for support of multiple technology and credential translation services (e.g. SAML -> X509 translation)* **<input here>**
- *Community level authorization/attribute based authorization to support different authorization levels for the users* **<input here>**
- *Web access and/or non-web access* **<input here>**
- *Need for delegation (e.g. execute complex workflows on behalf of the user)* **<input here>**
- *Support for different level of assurance credentials, and need to use the information about users with lower level of assurance credentials to limit their capability* **<input here>**
- *Requirements for high level of assurance credentials (e.g. to access confidential/sensitive data)* **<input here>**

7.5 *On HPC*

Describe any specific issue related to the use of supercomputers.

<input here>

7.6 Initial short/summary list for "test" applications (task 2.3)

Software used	*Software/applications/services required, configuration, dependencies (Describe the software/applications/services name, version, configuration, and dependencies needed to run the application, indicating origin and requirements.)* **C/C++ Java, Python with different libraries, CFITSIO, GSL, DJANGO framework (python) and Liferay framework (Java)**
Operating system requirements	**LINUX (scientific Linux) for servers, No restriction for clients**
Run libraries requirements	*Run API/libraries requirements (e.g., Java, C++, Python, etc.)* **C/C++, Java & Python**
CPU requirements (multithread,MPI, "wholenode")	**~2000 cores / 10-20 GPUs servers**
Memory requirements	**4-8GB per thread/core**
Network requirements	**10GB/s point to point connection**
Disk space requirements (permanent, temporal)	*Include the requirements for data transferring (upload and download of data objects: files, directories, metadata, VM/container images, etc.)* ***~>100PB (incremental starting from ~10PB/year)***
External data access requirements	**Interoperability cross-platform for clients**
Typical processing time	**Respect the data flow (~0.4-5.3 GB/sec) depending on event size (~10kB/event), the event rate (~600Hz) and the hours observable (~8hr)**
Other requirements	*Requirements for data synchronization* *Requirements for data publication* *Requirements for depositing data to archives and referring them* *Requirements for mobile application components for data storage and access* *Requirements for data encryption and integrity control-related functionality*

	TBD depends on defined CTA interfaces
Other comments	**<input here>**
Relevant references or URLs	• ***https://www.cta-observatory.org/*** • ***http://www.brera.inaf.it/astri/*** • ***http://www.inaf.it*** • ***http://www.oa-roma.inaf.it***

8 CONNECTION WITH INDIGO SOLUTIONS

<To be filled by INDIGO JRA >

8.1 IaaS / WP4

8.2 PaaS / WP5

8.3 SaaS / WP6

8.4 Other connections

9 FORMAL LIST OF REQUIREMENTS

<this will be further edited within WP2>

10 REFERENCES

R 1	CTA white pages
R 2	CTA Data Management Technical Design Review
R 3	
R 4	
R 5	