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Widefield Spectroscopic Telescope (WST)

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1. Introduction

This document contains the Data Management Plan (DMP) of the WST concept study. In order to fulfil the requirements for the Widefield Spectroscopic Telescope (WST) goals the concept study builds on heritage state-of-the-art telescope and instruments while developing new ideas and their feasibility for the unique capabilities of the WST. In this context, the re-use of any existing data to evaluate and develop the WST telescope supporting new MOS and IFS capabilities and feasibility according to the WST goals is of key importance.

In compliance with FAIR principles, this document utilizes the WST concept study Work Packages (WP) structure to outline, according to each WP activities, the data being used, the processing tools and products supporting the WST concept study. Information on findability, accessibility, Integration, and re-use of data and tools to ensure reproducibility of products, whether as part of deliverables or intermediate steps through the concept study are provided.

Further to the FAIR principles, the document also addresses research outputs other than data, and consideration related to the allocation of resources, data security and ethical aspects.

1.1. Applicable documents

AD1 WST Horizon Europe Deliverables D2 (WP1): Top-Level Requirements (TLR)

AD2 WST Horizon Europe Deliverables D12 (WP3): Telescope L1 Requirements (TL1R)

AD3 WST Horizon Europe Deliverables D21 (WP6): Communication. Dissemination, and Exploitation Plan (CoDEP)

AD4 WST Horizon Europe Deliverables D23 (WP6): Code of Conduct (CoC)

1.2. Reference documents

RD1 WST white paper, Mainieri et al. 2024, arXiv:2403.05398

RD2 Horizon Proposal: WST – The Wide-Field Spectroscopic Telescope, https://cordis.europa.eu/project/id/101183153

RD3 The WST Chronicle: Chronicle Nro.1

1.3. Acronyms and definitions

Following is a list of adopted conventions, acronyms and definitions used in this document.

Acronym	Definition
ADQL	Astrophysical Data Query Language

AGN	Active Galactic Nuclei
AIP	Astrophysics Institute Potsdam
ASCII	American Standard Code for Information Interchange
BagPipes	Bayesian Analysis of Galaxies for Physical Inference and Parameter EStimation
Blue MUSE	Blue-optimized Multi Unit Spectroscopic Explorer for the VLT
CAD	Computer-Aided Design
CCD	Charge-coupled device
CDS	Strasbourg astronomical Data Center
CFD	Computational Fluid Dynamics
CFHT	Canada France Hawaii Telescope
CMOS	Complementary Metal-Oxide-Semiconductor
CoC	Code of Conduct
CoDEP	Communication. Dissemination, and Exploitation Plan
DESI	Dark Energy Spectroscopic Instrument
DRS	Data Reduction Software
EAGLE	Evolution and Assembly of GaLaxies and their Environments
EDI	Equity, Diversity, and Inclusion
ESO	European Southern Observatory
ETC	Exposure Time Calculator
FEA	Finite Element Analysis
FAIR	Findability, accessibility, interoperability, and reusability
FE models	Finite Element models
FITS	Flexible Image Transport System
GALAH	GALactic Archaeology with HERMES
GitHub	GitHub - open-source version control system (VCS) called Git enabling code sharing using the Secure Shell Protocol (SSH) over unsecured network
HDF	Hierarchical Data Format – file format HDF4, HDF5 designed to store and organize large amounts of data
HERMES	High Efficiency and Resolution Multi Element Spectrograph
IFS	Integral Field Spectroscopy
INAF	Instituto Nazionale di Astrofisica
IVOA	International Virtual Observatory Alliance
JSON	JavaScript Object Notation
LCA	Life Cycle Assessment
L1	Level-1
MAMBO	Mini Astrophysical MeV Background Observatory
MOONS	Multi Object Optical and Near-infrared Spectrograph for the VLT
MOS	Multi-Object Spectroscopy
MOS-HR	Multi-Object Spectroscopy High Resolution
MOS-LR	Multi-Object Spectroscopy Low Resolution
MUSE	Multi Unit Spectroscopic Explorer for the VLT
NGCII	Next Generation Controller II
pPXF	Full Spectrum Fitting with Photometry for Stars and Galaxies
Prospector	Python code for Stellar Population Inference from Spectra and SEDs (Spectral Energy Distribution)
Redrock	Redshift fitting for spectroperfectionism

SDSS	Sloan Digital Sky Survey
Simba	Cosmological Simulations with Black Hole Growth and Feedback
SIPGI	Spectroscopic Interactive Pipeline and Graphical Interface
SNR	Signal-to-Noise Ratio
SpecTel	Spectroscopic Survey Telescope
STEP-file	Data exchange form for 3D objects in computer-aided design (CAD) - STEP-file is ASCII text format defined in ISO 10303-21
STFC	Science and Technology Facilities Council
TAP	Table Access Protocol
TLR	Top Level Requirements
TL1R	Telescope Level-1 Requirements
UKRI	United Kingdom Research and Innovation
VISTA	Visible and Infrared Survey Telescope for Astronomy
VLT	Very Large Telescope
VPHGs	Volume Phase Holographic Gratings
WP	Work Package
WST	Widefield Spectroscopic Telescope
Zebase	Zemax database - patented optical designs pre-built as Optic Studio models
4MOST	4-metre Multi-Object Spectroscopic Telescope for the VISTA

2. FAIR within the WST Work Packages

We present FAIR compliance in context with the WST work packages structure to facilitate and outline aspects of making data findable, accessible and interoperable within and across work packages through the WST concept study life cycle and beyond [RD2].

The WST will be using a FAIR –compliant website that will represent a main reference repository of open -access data, tools and products that will results from the WST concept study (https://www.wstelescope.com).

2.1. Work Package 1 (WP1) - Management

Management and the PO office has a key role in directing the various work packages through the requirements and applicability of the FAIR principles. As such, it oversees and administers the coordination of trusted repositories through SharePoint, under UKRI Science and Technology Facilities Council (STFC), and the WST website, under INAF. The SharePoint site is enabling share of documentation, metadata, data and products of sensitive nature among the WST consortium members. The WST website repository has been identified as reference site for documentation, metadata, data and products defined as non-sensitive as per Horizon agreement.

The WST website trusted repository will be used to facilitate FAIR open-access data, tools and products (https://www.wstelescope.com). The website is undergoing a redesign and transition to a European Union domain extension, such as .eu site, that will be operational by the end of 2025 [AD3].

Common practice across the WPs is the use of SharePoint to store and exchange documents and conduct collaborative work. The main platform of communication within the WST project is a Slack platform - WST Slack – for consortium members only. The WST Slack platform enables organizational communications and activities within and across work packages, such as coordination of meetings, posting of recorded minutes, access and sharing of presentations, reference documents, workplans, and other useful documentation.

2.2. Work Package 2 (WP2) - Science

The Science work packages will generate astronomical catalogues using both observational data and simulations. These catalogues will be needed to develop a coherent survey program and demonstrate that the WST concept, running parallel observations of MOS and IFS, is the more scientifically efficient way to address the identified science questions [RD1]. Such catalogues will be either astronomy standard Flexible Image Transport System (FITS), Hierarchical Data Format (HDF5), and generic Excel (xlsx) or ASCII format.

2.2.1 WP2.2 Cosmology - WP2.3 Extra-galactic - WP2.4 Galactic - WP2.5 Time-domain - WP2.6 Survey plan

The science WPs will use astronomical data or simulations that are already publicly available.

For the Galactic science cases we will use data from the Gaia satellite, in particular from the already publicly available Gaia Data Release (DR3) [1], and potentially from the upcoming Gaia DR4 [2}.

The WP2.2 cosmology and WP2.3 Extra-galactic we will use numerical simulations which are already publicly available through multiple repositories. Example of numerical simulations that will be used for both WPs are: IllustrisTNG [3], EAGLE [4], Simba [5].

In addition, to produce empirical mock catalogues of galaxies and AGN, the science working groups will make use of the Mini Astrophysical MeV Background Observatory (MAMBO) workflow by Lopez-Lopez et al. (2024)[6], publicly available on GitHub [7].

The expected size of the produced catalogues is of order of 10 million objects, which is approximately equivalent to 100 GB.

WST Science data will be accessible through the WST website trusted repository as open-access data, tools and products (https://www.wstelescope.com).

2.2.2 WP2.7 ETC

The Exposure Time Calculator (ETC) will compute the achievable signal to noise ratio (SNR) for all foreseen observational modes of WST and for a large set of target types. Another important functionality of the ETC will be to produce observed 1D spectra, folding in the atmospheric and instrumental signature on a user provided spectra.

The ETC will be fully written in Python, therefore it will be based on open-source software. To compute the sky background, the ETC will make use of the publicly available SkyCalc web-application based on the Cerro Paranal Advanced Sky Model [8, 9, 10].

The ETC will be made publicly available through the WST website repository to all scientific community. In addition, the raw code as well as the databases, will be hosted in a GitHub repository. Any user will therefore be able to download the raw code and follow instructions on the related notebooks to execute the ETC locally on their machine/computer.

We foresee that the raw code will be less than 10 MB in size. The ETC science template database would be on the order of 50 MB. Sky and atmosphere transmission database would be on the order of 50 MB. Other instrument specific features database (e.g. instrument total efficiency/transmissions) would be on the order of 30 MB.

The ETC will use two main inputs. On one side the spectral template, either observed or simulated, provided by the science WPs, for which we foreseen a maximum size of 880 KB. In addition, FITS tables for survey simulations for the WP5.2 Facility Simulator (see 2.5.2), for which estimated size is in the order of 2GB for 10^6 simulations.

The planned output results generated by the ETC will be both plots displayed in the Webpage and a JSON dictionary which will contain the data plotted in the different figures, so that the users will be able to produce their own specific plots and results for scientific and technical publications. A JSON dictionary refers to a data structure in JSON (JavaScript Object Notation) format [11], which represents key-value pairs, similar to a dictionary in Python or other object-oriented programming language. JSON is widely used for data exchange between systems/users due to its simplicity and readability [12]. The expected size of the output JSON dictionary would be less than 15/20 MB.

2.3. Work Package 3 (WP3) - Telescope

The objective of Work Package 3 is to develop, critically review, and cost a unified conceptual design for the WST telescope package. This includes both the structural and optical configurations required to enable the Multi-Object Spectroscopy (MOS) and Integral Field Spectroscopy (IFS) capabilities of the observatory. The design effort will place particular emphasis on cost-effectiveness, risk mitigation, structural resilience, long-term maintainability, and sustainability.

The data input, the modelling software used, and the data outputs of this package are described in the following sections.

2.3.1 WP3.1 Telescope System

The telescope designs and simulations are based on the input of specific parameters derived from the Top Level Requirements (TLR) and the Telescope Level-1 (L1) Requirements (TL1R) for the WST facility (AD1, AD2).

All WST Telescope system produced data are sensitive and thus will be restricted to the WST consortium.

2.3.2 WP3.2 Optical design

The optical design activities will be carried out using OpticStudio (Zemax) [1], a widely used commercial software platform for the simulation and optimisation of optical systems. The output of this task will consist of a detailed optical design report, together with the corresponding Zemax files. These sensitive deliverables will be made available internally to the WST consortium.

2.3.3 WP3.3 Telescope opto-mechanics

This task will address the mechanical integration of the optical elements with the telescope structure. It will use as input the top-level (AD1) and Level-1 (L1) telescope requirements (AD2), which define the physical architecture, mass budgets, interface definitions, and mechanical envelopes. It will also incorporate the results of the optical design and structural CAD models. Sustainability-related requirements, in collaboration with the WP6.4, will be also considered.

The simulations will involve Finite Element Analysis (FEA) [2], performed using commercially available software such as Ansys, and will include realistic environmental conditions provided by the WP6.2 Site selection (see 2.6.2). The results will be documented in design and analysis reports and will include updated CAD models. These sensitive outputs will be distributed within the WST consortium.

2.3.4 WP3.4 Telescope structure

The structural design of the telescope will be based on input from the top-level and L1 requirements, the optical design, environmental constraints from the WP6.2, and the instrument design volumes and mass specifications. Modelling will be carried out using CAD tools, Finite Element Analysis, and Computational Fluid Dynamics (CFD), relying on commercially available software platforms.

The outputs will include detailed design and analysis reports, finite element models, CAD files, and architectural documentation. These sensitive materials will be disseminated internally within the consortium.

2.3.5 WP3.5 Telescope enclosure

The design of the telescope enclosure will consider both structural and environmental aspects, including turbulence within the dome and its impact on image quality. Inputs will include the top-level and L1 requirements, telescope CAD files, environmental data from the WP6.2, and the volume and mass of the instruments. Interfaces with WP6.2 (site selection) and the WP6.4 (sustainability) are particularly relevant to this task.

The enclosure simulations will be performed using CAD modelling, Finite Element Analysis, and CFD tools. The results will be compiled in design and analysis reports, accompanied by CAD and FE models and documentation on the physical architecture. These sensitive outputs will be shared with the WST consortium.

General Considerations on Sustainability

The design will include an assessment of the power and cooling requirements of the telescope, in collaboration with the WP6.4 Sustainability (see 2.6.4). Although direct optimisation for sustainability may be limited, many aspects of the design process such as reducing moving mass and improving system reliability, resources availability, and maintainability will inherently support sustainable solutions. Key factors include the choice of materials, physical layout, and strategies for managing component obsolescence over the lifetime of the facility.

2.4. Work Package 4 (WP4) - Instrument

The overall objective of this work package is to develop the design of the instrumentation required to gather astronomical data for the Wide-field Spectroscopic Telescope (WST). Each design will be subject to a review to verify the performance of the design meets the top-level requirements for WST. Following review, selected designs will also be discussed with industry to develop cost estimates and verify the suitability of the design for industrialized production processes. The technical risk associated with each design will also be evaluated.

The data input to this work package, the modelling software used, and the data outputs are described in the following sections. A top-level overview of all data input, software, and data output is provided in the sub-section for WP4.1. The other instrument work packages are numbered WP4.2, WP4.3, ..., to WP4.9, with each work package containing a different sub-system part of the overall instrument system. Each of these sub-sections will describe data specific to that work package.

2.4.1 WP4.1 Instrument system

The purpose of the instrument system work package is to provide leadership and coordination of the other eight work packages. This work package also tracks the progress of the design activities and reports on progress to the project office. The instrument coordinator also provides technical guidance to the other engineers working on the project and hence uses a wealth of heritage data from other projects to provide examples of how to design instrumentation.

The input data for the instrument system design process is the top-level requirements (TLR) document (AD1). The top-level requirements document provides a list of the functions the instruments are expected to perform.

The instrument system input data also includes heritage data from previous design studies and previously published data on WST. For example, prior to WST there was a design study called SpecTel [1], and data related to this project is available on the WST public website. Heritage activity that was performed leading up to the current WST Horizon study has been published via Society for Photonic Instrumentation Engineers (SPIE) conference proceedings in "WST: Widefield Spectroscopic Telescope: addressing the instrumentation challenges of a new 12m class telescope dedicated to widefield multi-object and integral field spectroscopy" [2]. The SPIE digital library is open to anyone, however access to published data requires institutional access credentials or independent registration and payment.

Many of the heritage publications being used by WST, and data output from WST, are being made available on the Cornell University arXiv website. These files are generally accessible by anyone for free. Copy of the SPIE paper "WST: Widefield Spectroscopic Telescope: addressing the instrumentation challenges of a new 12m class telescope dedicated to widefield multi-object and integral field spectroscopy" is available through arXiv [3].

The WST Instrument system non-sensitive data will be accessible through the WST website (https://wstelescope.com), which will host a trusted repository for open-access data, tools and products.

A project as complex as the instrumentation for WST will access heritage data from a variety of sources in addition to those already mentioned. This heritage data is applicable to all WP4 work packages. The following list provides some examples of heritage data that are an input to WST.

Many textbooks are available describing how to design and build astronomical instrumentation. A good example is this textbook: Spectroscopic Instrumentation Fundamentals and Guidelines for Astronomers, Authors: Thomas Eversberg, Klaus Vollmaan, Publisher: Springer

A wealth of data regarding past, present, and future instrumentation projects can be found on the websites of existing observatories. Here are some examples of observatory websites:

- https://www.eso.org
- WEAVE - instrumental overview
- Dark Energy Spectroscopic Instrument (DESI)

There are many University research groups that design and build astronomical instrumentation, and much useful heritage data are available on their websites. For example, information regarding the instrumentation activity at CRAL can be found on this webpage: Instrumentation | CRAL.

The SPIE digital library (https://www.spiedigitallibrary.org/) has already been mentioned. This resource contains the complete catalogue of SPIE conference proceedings covering all Astronomical Telescope and Instrumentation conferences. Also provides access to SPIE published text books and online training courses. Access to SPIE products usually must be paid for although some publications are available as open access.

The scientific and engineering community also publishes in journals. Here is a list of a few journals that will provide input data to WST instrumentation:

- Monthly Notices of the Royal Astronomical Society (MNRAS; Monthly Notices of the Royal Astronomical Society | Oxford Academic). This journal is widely used for publishing papers regarding telescope and instrumentation designs.
- Applied Optics (Applied Optics). This journal is widely known for publishing papers about optical design and engineering.
- Publications of the Astronomy Society of the Pacific (PASP; Publications of the Astronomical Society of the Pacific - IOPscience). This journal is widely known for publishing content regarding telescopes and instrumentation.

If an instrument design is developed for a commercial application, it is often protected via a patent. Some of the patent databases are accessible and provide input data about how to design an instrument. A good example of this is the commercial product, Zebase, a database of patented optical designs that are pre-built as Optic Studio models. This database can provide a good starting point for an optical designer to find a lens or telescope design. Zebase is sold as an optional extra of the Zemax optical design software [4].

A considerable amount of input data and information is available on supplier websites regarding specifications, performance, and cost of commercially available items. For example, information regarding the performance of Charge-coupled device (CCD) and Complementary Metal-Oxide-Semiconductor (CMOS) detectors is available on the Teledyne E2V website for imaging and scientific applications (imaging: https://www.teledyne-e2v.com/en-us/solutions/imaging/; scientific: https://www.teledyne-e2v.com/en-us/solutions/scientific/). In addition, commercial products are usually available with a data sheet that describes the technical characteristics and how the product functions. For example, when designing a lens, data regarding the properties of glass can be obtained from the glass supplier, such as the Schott glass catalogue [5].

The design process will also use Zemax optical design files and opto-mechanical CAD files available from WST collaborators (see WP3 section 2.3.2 and 2.3.3), some of which may be commercially sensitive.

The following list is of the software being used to design the WST instruments. This list is applicable to many of the work packages in WP4. Both commercially available software and custom written software will be used for WP4 Instruments.

Commercially available software:

- Altium Designer – Electronic cad software (https://www.altium.com/altium-designer)
- Ansys Zemax Optic Studio – optical design software (https://www.ansys.com/products/optics/ansys-zemax-opticstudio)
- Ansys FEA (https://www.ansys.com/campaigns/ansys-structural-analysis-software)
- COMSOL Multiphysics – Multiphysics software design platform (https://www.comsol.com/comsol-multiphysics)
- Lambda Research Corporation TracePro – opto-mechanical modelling software (https://lambdares.com/tracepro)
- LTSpice – Electronic simulation software (https://www.analog.com/en/resources/design-tools-and-calculators/ltspice-simulator.html)
- nTop – computational design platform enabling iterative designs to tailor products to unique requirements (https://www.ntop.com/)
- Dassault Solidworks – easy-to-use 2D and 3D product development solutions (https://www.3ds.com/products/solidworks)
- Autodesk Inventor – 3D modelling software for designers and engineers (https://www.autodesk.com/au/products/inventor/overview)
- MathWorks MATLAB – programming and numeric computing platform to analyse data, develop algorithms, and create models (https://www.mathworks.com/products/matlab.html)
- Microsoft Visio – creation of diagrams, schematics, and technical drawings for inclusion in design reports (https://www.microsoft.com/en-us/microsoft-365/visio/flowchart-software).

Custom software: some of the design and analysis is done using custom Python or Matlab scripts and algorithms. Some of this software is likely to be commercially sensitive and not available outside the WST consortium. Where software or tools developed through the concept study are considered publicly available, they will be made accessible via GitHub or the WST website.

The output data of the instrument design process is generally a CAD model of the instrument, and results of performance simulations. The output file size will vary depending on the type of file. A simple spreadsheet or text document may only be a few kilobytes whilst a complex mechanical model of an instrument might be many gigabytes.

Files generated during the WST activity are primarily stored on the UKRI-STFC SharePoint site. This information is only visible to members of the WST consortium due to its sensitive nature. Files that are accessible to the public will be made available via the WST website (https://www.wstelescope.com/) and on other platforms described earlier.

Presentations and posters given at conferences may be available on the conference websites. Where possible, these will be made publicly available on the WST webpages. Note that some conferences do not allow public access to conference materials.

2.4.2 WP4.2 Positioners

In this sub work package, we will study the fiber positioners and the modularity of the positioner holder system in the focal plane. We have four different positioners design and two modularity concepts, one concept of positioner per team. For modularity, two teams study the triangular concept and other two teams are focusing on the linear concept.

The work is leveraging heritage designs for the linear and triangular modular concepts. The "inLine" concept is inspired by the Sphinx, a massively multiplexed fiber positioner for the CFHT's Mauna Kea Spectroscopic Explorer (MSE) Telescope [6], which is using tilting spines. Several prototypes have been constructed and demonstrated the suitability and impact of tilting spines on the overall survey efficiency for MSE – survey efficiency is a key goal for the WST design.

The “triangular” approach is inspired by the MegaMapper [7], a stage-5 spectroscopic instrument concept for the study of inflation and dark energy, which uses robotically actuated multimode fibers [8] implemented in the Dark Energy Spectroscopic Instrument (DESI) [9]. It involves a Magellan-like telescope and newly designed wide field, coupled with DESI spectrographs, and small-pitch robots to achieve multiplexing of at least 26,000 - the goal for WST is 30,000.

Input and software used in this work package are listed in section 2.4.1. Each team is responsible for producing output documents that will describe every concept design supported by CAD designs. The team will produce a trade-off selection criteria to summarize all trade-off parameters in a synthetic report.

2.4.3 WP4.3 Fibre

This sub work package is for the design of the optical fibre cables that carry the light from the telescope focal surface to the spectrograph. Data input to this work package that is not already described in section 2.4.1 will be data from commercial manufacturers of optical fibres, such as Ceram Optec. An example data sheet for the type of optical fibre that might be used in WST can be found here: Optran UVWFS / Ceram Optec. Other data input to this work package will be the interface with other parts of WST such as the telescope structure and the spectrographs. These interface data will likely be CAD files that might not be accessible outside the project.

2.4.4 WP4.4 MOS-LR

This sub work package concerns the study of the MOS Low-Resolution (MOS-LR) spectrograph options in terms of optical design and opto-mechanical implementation. The main challenge is to achieve the extremely fast camera optics required to ensure projection of spectra onto reasonably sized detectors with reasonable spectral and spatial sampling, considering manufacturing, integration, and maintenance aspects. Metrics are being developed to allow trade-offs in terms of cost and performance.

Input and software used in this WP are already listed in section 2.4.1. Optical designs will be elaborated and analyzed using Ansys Zemax Optic Studio – optical design software. This software also outputs STEP-files enabling interoperability and exchange with mechanical design software. Starting points for optical designs are recent MOS realizations such as SUBARU-PFS [10] and VLT-MOONS [11], but significant evolutions of these designs will be necessary to reach WST requirements and constraints.

Important interfaces with other work packages include WP4.3 Fiber for discussions about the fiber slit requirements and WP4.7 Advanced technologies for discussions around grating and detector feasibility and performance. In particular, the evolution of detector technology makes it challenging to fix detector-related parameters, and it is likely we will have to resort to educated guesses. The availability of curved detectors is likely to open interesting avenues in terms of optical design. Further interface discussions with WP3 will be necessary, concerning the fiber input side and stray light concerns, as well as localization and access within the telescope enclosure.

2.4.5 WP4.5 MOS-HR

The MOS High Resolution (MOS-HR) sub work package is creating the opto-mechanical design of the instrument that will provide WST with the capability to observe spectra at resolving power of 40,000.

Input data into the opto-mechanical design process will include previously published data on other spectrograph designs. An example is HERMES, a high resolution MOS constructed for the Anglo-Australian telescope [12, 13]. The next generation Multi-object Optical and Near-IR spectrograph (MOONS) [14], for the Very Large Telescope, will also be heritage input data for the opto-mechanical design.

The opto-mechanical design and performance analysis will be carried out using the industry standard software tools described in sub-section 2.4.1. This work package will interface work with the WP3.2, 3.4, and 3.5.

The output data from this software will be sensitive CAD files that will not be publicly available. A summary of the MOS-HR design will likely be presented at a conference, for publicity purposes, or written up as a research paper. In this case some of the data output from this work package will be publicly available.

2.4.6 WP4.6 IFS

The Integral Field Spectrograph (IFS) work package is creating the opto-mechanical design of the instrument that will provide WST with the capability to measure astronomical data cubes of large areas of sky. A data cube is a type of astronomical data product that contains data with three axes representing X and Y image position on sky and the wavelength at each image position.

Input data to this sub work package will include heritage data from previously constructed IFS systems such as the Multi Unit Spectroscopic Explorer (MUSE) [15], and systems still under design, such as the blue-optimised large field integral field spectrograph Blue MUSE [16] for the VLT.

The opto-mechanical design and performance analysis will be carried out using the industry standard software tools described in sub-section 2.4.1. This work package will interface work with the WP3.2, 3.4, and 3.5.

The output data from this software will be sensitive CAD files that will not be publicly available. A summary of the MOS-HR design will likely be presented at a conference or meeting, for publicity purposes, or written up as a research paper. In this case some of the data output from this work package will be publicly available.

2.4.7 WP4.7 Advanced technologies

The advanced technology work package includes the detectors, detector cooling systems, electronics, and dispersion elements (diffraction gratings) that will be used by the instruments. The advanced technology name refers to the situation that some of this technology is currently not commercially available, such as e.g. large curved detectors for scientific use.

Custom Python code is used for the theoretical predictions of diffraction grating efficiency curves. This code is commercially sensitive and is not available to the general public but some information has been published in relation to the use of Volume Phase Holographic Gratings (VPHGs) to increase diffraction efficiency while being tailored according to the spectrograph requirements [17].

The overall objective for WP 4.7 is to identify an applicable combination of suitable detectors and associated electronics for the WST spectrograph instrumentation. The outcome will be a conceptual design report that defines the detector specifications and how the detector concept can fulfil those, as well as proposing an associated electronics concept, both potentially with remaining development effort. This is accompanied by cost and schedule information.

Detector system methodology

This process can be divided in two steps:

A.) Concentrate onto the choice of suitable state of the art detectors for the visible detector systems, and their controller systems, for the different spectrograph instruments of WST.

B.) The detector choice will also significantly influence the design of a customized detector controller, which within this study has 2nd order priority. However, needs to be a custom compact solution for which boundary requirements will be defined.

A main first step of this process is the definition of requirements in connection with the project high level requirements, as well as the different spectrograph and science requirements for WST (MOS-LR, MOS-HR, and IFS). This is a complex undertaking due to the various interfaces with three different sets of iterative spectrograph optical designs (e.g. Schmidt camera and/or mosaics with different pixel stability), as well as the separate cryostat work-package, and the end-user's different observation programs.

This definition process is based on the experience of a team of detector engineers and project managers at ESO, who have worked on state-of-the-art CCD and CMOS detector systems in the past years (in one case more than 30 years at ESO).

Step A

The new component in the analysis is the fact that on the WST time-line it is not very likely that state of the art CCDs will be still available or under sufficient development. In contrast, scientific CMOS detectors are currently evolving very fast, and the required large size scientific CMOS detectors is achievable, making them the detectors of choice for WST. Some information regarding current state art performance of CCD and CMOS detectors is available by Teledyne E2V for both imaging and scientific applications (imaging: https://www.teledyne-e2v.com/en-us/solutions/imaging/; scientific: https://www.teledyne-e2v.com/en-us/solutions/scientific/).

The current challenge is to find and/or custom develop scientific CMOS detector(s), which combine the required properties to the highest extent within one device.

To ensure a comprehensive evaluation, the study will follow dual paths:

CCD track: We will start with the current (at ESO) well known CCD portfolio to provide a performance benchmark and a potential fallback solution.

CMOS track: Engage with leading design houses / manufacturers of large format scientific CMOS. ESO has teamed up with leading manufacturers under NDA to access unpublished roadmap info and assess future device or feature availability. The market is carefully studied, and the options for planned and/or custom devices evaluated with respect to defined requirements. Another possible step is prototyping, testing, and characterization (if time and budget allows) for the most promising WST candidate CMOS devices, and an evaluation of yet unknown device properties to de-risk critical performance parameters.

In parallel to these activities, it is essential to watch the trends in scientific CMOS design and fabrication to be able to extrapolate the up-coming technology to their final application, based on the WST timeline.

Another area of conceptual study are the curving techniques for detectors (together with modified optical design of the spectrographs), which enable better system image quality, following a similar but separate and more specialized development approach. This is – amongst others- based on initial R&D for curved detectors at ESO in the past.

Step B

There are several dependencies on the chosen detector, as of the available / necessary (digital) detector output interface and the need for a compact low power controller, featuring detector operational supply and data acquisition. As much as possible this will be a modular design featuring FPGAs, potentially in connection with building blocks of the ESO's Next Generation Controller II (NGCII) platform (https://www.eso.org/sci/future/techdev.html).

The overall result will be a conceptual study report, listing the respective findings, comparing different options with objective evaluation criteria of important device parameters versus established requirements and projecting the budget and development path timeline for the required components.

2.4.8 WP4.8 Calibration

The calibration sub work package is concerned with designing an illumination system for WST that injects light into the optical systems to allow the scientific data to be calibrated. The output data from the spectrographs (WP4.4, WP4.5, and WP4.6) is in the format of a raw image, in which the pixel location X, Y, and light intensity is known. To convert this raw data into an astronomical spectrum of scientific use requires the information in each pixel to be calibrated. This means converting from pixel X, Y to wavelength and location of the pixel on the reconstructed image of the astronomical object. Wavelength calibration is generally done by illuminating the spectrograph with a known spectrum, such as that from a hollow cathode lamp.

Input data to this work package includes published data on the spectra of commercially available hollow cathode lamps which is available at the US National Institute of Standards (NIST) Physical Measurement Laboratory Atomic Spectroscopy Database here: Atomic Spectroscopy Databases | NIST.

The optical design of the calibration system will be done using a combination of Ansys Zemax OpticStudio and TracePro, as described in section 2.4.1.

The output data from this software will be sensitive CAD files that will not be publicly available.

2.4.9 WP4.9 Future development

The purpose of this sub work package is to monitor the status of the designs of the other work packages and recommend areas where future upgrades to WST would be possible. The input data to this work package is then the output data from the other WST work packages including science, telescope designs, and instrument designs. Future upgrades will also include new technology that can be used to improve sustainability. The sensitive output data of this work package will be made available internally to the WST consortium. If a particular technological development need is identified, such as improved types of fibre connector, this information will be made publicly available, for example by discussion at a conference, to make commercial manufacturers aware of the need for new technologies.

2.5. Work Package 5 (WP5) – Operation

The overall objective of this work package is to develop the Operational Concept and Science Data Flow. It will define the needs, in terms of tools, staff effort and hardware to enable efficient implementation of the Survey Plans, archive and deliver science-ready data, and operate of the facility.

The data input to this work package, the modelling software used, and the data outputs are described in the following sections.

2.5.1 WP5.1 Operation System

WST Operation system data will be accessible through the WST website trusted repository as open-access data, tools and products (WST website: https://wstelescope.com).

2.5.2 WP5.2 Facility simulator

This WP will develop the Facility Simulator (FS), a survey scheduler software with the goal of optimizing the usage of the facility and supporting facility architecture trade-off decisions. The software will be created based on the experience gained in developing similar codes for other projects that, in this sense, will be *re-used*. Two heritage-baseline codes are considered for the scope:

- the 4MOST visit planner [1]; this code was developed to define the observation strategy for the 4MOST spectroscopic survey, optimizing the tiling pattern based on the requirements of the various concurrent 4MOST sub-surveys. The algorithm was developed with a flexible design that makes it adaptable to other instruments/surveys such as WST. The main foreseen update that will be made is the addition of the IFS, which is not present in the current implementation.
- the MOONS fiber-target allocation software (MOONLight) [2, 3]; this code was developed to optimize the fiber/target allocation of the MOONS spectrograph; the scalability of this algorithm to a much larger number of fibers will be studied. This algorithm requires detailed knowledge of the positioner hardware characteristics, so it cannot be used until they are fully defined. A statistical approach (already implemented in the 4MOST visit planner) will be used as a placeholder until the final positioner decision is made.

The FS code will be stored in the INAF GitLab repository [4]. The repository will be kept private. The software will be used only within the framework of the Horizon concept study by trained users. The development of a user-friendly version for public release is not foreseen within this concept study .

The input for the FS are the catalogs of the various reference surveys as defined by Science Working Groups. Catalogs will be gathered and fed to the FS by the Survey

Plan created by the WP2.6. Input catalog format will be FITS files. Details on the input catalogs can be found in section 2.2.1.

The output of each run of the FS will be the 5 years observing schedule of the facility. This output will be organized as a set of files (most likely one per survey) in Hierarchical Data Format (HDF); the global size of these files is estimated to be around 1 TB. Considering the project timeline, a plausible estimate of the number of simulations can be 10, for a total storage requirement for WP5.2 of 10 TB. This storage size is easily affordable with off-the-shelf resources available in any of the institutions involved in the FS development, therefore no cloud or distributed storage is needed.

2.5.3 WP5.3 MOS data

Data from public surveys, like SDSS [5], DESI Data Release 1 [6], Gaia-ESO [7], and GALAH [8] at various processing stages (from raw to fully reduced) will be used to evaluate the efficiency of different data models and make realistic estimates of the processing power and time needed. For the purpose of testing the performance of currently available scientific analysis tools, simulated spectral libraries are also available from previous published works such as Zibetti et al. 2017 [9], Candebat et al. 2024 [10], and de Laverny et al. 2012 [11].
Data from public surveys will be obtained from their respective public repositories, while simulated data are available through the INAF proprietary cloud system.

We foresee to employ publicly available reduction pipelines from ESO, or SIPGI [12], as well as public analysis software such as redrock [13], pPXF [14], BagPipes [15] and Prospector [16] to evaluate the workload required by the data reduction and (possible) scientific analysis.

Up to ~100 Gb are expected to be used in our testing, in the format of FITS files (binary images or tables). We do not expect any use of the re-processed data outside of the current project.

2.5.4 WP5.4 IFS data

The activities of this WP include deriving some requirements for a computing platform able to process and reprocess data from the IFS. The concept will leverage the knowledge of data similar to those that will be expected for the WST, assuming a scaling factor of 12, to test hypothesis such as amount of memory and number of cores related to processing capability needs on currently available computers at the Astrophysics Institute Potsdam (AIP). This work will be conducted also with focus on improvement on current practices in view of sustainability.

VLT/MUSE data [17] and the VLT/MUSE data reduction pipeline [18] will be used for this work, leveraging from the similarity between the two instruments. Raw spectroscopic data from MUSE spectrographs stored as FITS file will be used. Data is downloaded from the ESO archive, and both science and calibration exposures will be used.

A maximum of 10GB of raw data will be re-used and possibly replicated to scale to the same factor as WST IFS. No new data will be generated or additional software.

The elaboration of the WST IFS will be based on the following assumptions in terms of data types, size/memory allocation, and ESO Phase 3 standards [19] as outlined below.

Data types

- single raw data exposure of about 10GB
- single data cube greater that 35GB
- more than 215TB of raw data per year (including daily calibrations).
- a minimum of 320 TB of reduced data (not including catalogs or other final products)

Products following ESO Phase 3 standards

For data cube the FITS will support:

- a primary header with metadata reflecting observation conditions
- one FITS extension for data (flux)
- one FITS extension for variance
- one FITS extension for Data Quality Flags following.

For other products such as catalogs, the format will make use of FITS tables (see ESO Phase3 standards).

Raw data files will be stored as FITS files with a primary header handling all information relevant for the whole IFS and then one extension per detector, each of them hosting the metadata specific to a given detector). Each FITS extension of raw data would host a 2D image if a CCD detector is chosen, or a cube allowing the various readout and non-destructive readout in case a CMOS detector is chosen.

2.5.5 WP5.5 Data archive

The archive will use International Virtual Observatory Alliance (IVOA) standards, in particular Table Access Protocol (TAP) [20] for querying, and the ObsCore data model for raw data, and possibly the Spectrum data model for cataloging reduced spectra [21]. The database will be stored in a distributed PostgreSQL system, with appropriate indexing and celestial coordinates systems. Standard TAP libraries such as those from the Strasbourg astronomical Data Center (CDS) will be implemented, along with Astrophysical Data Query Language (ADQL) libraries and validators [22]. Additionally, an IVOA Simple Spectrum Access service [23] (or its successor) will be developed based on the TAP service described above. This will allow querying directly for raw and reduced spectra.

Final data volumes will depend on the outputs of the MOS and IFS Data Reduction Software (DRS) packages and final survey design. No data will be produced during the design study.

2.5.6 WP5.6 Operational model

The activities of WP5.6 include to derive an Operational Model to satisfy the science and survey requirements, considering the different technical options for the facility and their identified modes. The starting point will be based on our vast experience with ESO operational models such as VLT-MOONS [24] and mostly VISTA-4MOST [25], but with significant freedom for adaptation to the requirements of the WST facility.

This WP will generate an Operational Concept Document capturing the selected observing modes/configurations, as required for definition of calibration references and procedures, defining also the Operational Software Top Level Requirements, as well as the initial survey facility Operational Concept.

2.6. Work Package 6 (WP6) – General Facility

The general facilities work package consists of the following tasks: telescope site selection, outreach, communication and dissemination activities, sustainability study of environmental impacts, and the equity, diversity and inclusion activities. The site selection (WP6.2) is a key constraint on the telescope design and to the environmental study. There will be two-way flow of design information and guideline advice between the technical WPs and the sustainability tasks. Analogously there will be regular interactions between the full Consortium and the Communication team (WP6.3) for the coordination of outreach and dissemination of available information. The WP6.5 equity, diversity and inclusion (EDI) team will form a committee to ensure a fair representation of the broad and diverse community of the WST consortium in all its working structures.

The data input to this work package, the modelling software used, and the data outputs are described in the following sections.

2.6.1 WP6.1 Facility Coordination Selection

The WST Facility Coordination data will be accessible through the WST website trusted repository as open-access data, tools and products (https://www.wstelescope.com/).

2.6.2 WP6.2 Site Selection

Sites of interest for the WST project will be studied using modern atmospheric turbulence instrument, such as the Rings New Generation Scintillation Sensor (RINGSS) instrument [1, 2]. A RINGSS instrument has been built at ESO for the purpose of facilitating the monitoring of atmospheric conditions at various sites with the goal to support the ESO science operations [3]. Meteorological and atmospheric turbulence data, obtained by ESO under these new efforts will be also available to the WST project under a synergistic collaboration.

The two sites of interest for the WST are in the Region of Antofagasta, Chile:

- La Chira: historical meteorological, seeing and vertical profile of the turbulence data is available for the period December 2006 until April 2007;
- Ventarrones: historical meteorological, seeing and vertical profile of the turbulence data is available for the period May 2009 until April 2010.

The initial statistical characterization of candidate sites for the WST uses data that have been obtained by the ESO's Atmospheric Site Monitoring team to support the site selection and monitoring of the VLT telescope. The instruments used to obtain this data consists of:

- Weather stations;
- Differential Image Motion Monitor (DIMM) instruments, for atmospheric seeing information;
- Multi-Aperture Scintillation Sensor (MASS) instruments, used to monitor the vertical profile of the Cn2 (spatial variance in the air index of refraction at optical wavelength), and derive information on free atmosphere seeing, fraction of the turbulence found in the ground layer (i.e. closer to the surface), and coherence time of the turbulence.

For the sites environmental characterization the following tools will be used:

- Python programming language [4]. Python is licensed under the Python Software Foundation License (PSFL) [5]. This is a permissive license which imposes no restrictions for its use and distribution, as is the case for the use of python for the handling of data in scientific environments.
- Matlab commercial data analysis platform will be used for the analysis of environmental conditions intended for the WST. Matlab, license 9.14.0.2337262 (R2023a) update 5, owned by the ESO.

Meteorological and atmospheric turbulence data for the Paranal Observatory is publicly available from the ESO's Ambient Conditions Database [6]. A description of the data available and its physical units are found via the ambient conditions help page [7]. The whole ESO's ambient conditions data, historical and current, are free to be downloaded and used by the international science community. All historical data is found in the ESO's Product Data Management (PDM) database. The links to the various sites, of interest for the WST project, for which historical data are available are listed under document [8]. The data has been stored as accessible ASCII files, where column are labeled to understand content and physical units.

For site comparison purposes, ambient conditions data obtained during the site characterization of the Armazones site, hosting the ELT, may also be used. This data was obtained by the Thirty Meter Telescope (TMT) project, and is free for everyone, worldwide, to use [9]. Other data (meteorological, and atmospheric turbulence) obtained by ESO for the Armazones site, is available from the ESO's ambient condition database and is freely available.

2.6.3 WP6.3 Communication

This sub package has a key role in the coordination and support of the WST WPs and the full Consortium for the outreach and dissemination of information related to the project. The information will be related to the WST Consortium publications to engage the science and technical communities outside the WST consortium. Activities will include newsletter items, Chronicle articles [RD3], social media posts, and public event/deliverables.

The WP6.3 has a leading role in the development of the WST Communication. Dissemination, and Exploitation Plan (CoDEP), which includes the WST Visual Identity and a detailed plan for the restyling and release of the WST website by the end of 2025 [AD3].

The WP6.3 team will work closely with the WP6.5 EDI team to ensure respect of the WST Code of Conduct (CoC) [AD4] across the outreach activities along with policy feedback throughout the WST concept study.

2.6.4 WP6.4 Sustainability

In view of the European Green Deal [1], and EU commitment to become climate neutral by 2050, by reducing the net greenhouse gas emissions by at least 55% by 2030 compared to 1990 levels, urgent considerations are needed within the astronomy community. Knödlseder et al. 2022 [2] carried out the first comprehensive carbon footprint estimate of astrophysical research infrastructures and identified an average of 36 Tons of CO^2/astronomers/year solely coming from ground-based and space-based missions.

Sustainability must be addressed from the concept design phase of new astrophysical infrastructures. To ensure that environmental considerations are integrated early in the WST development process the Life Cycle Assessment (LCA), commonly used in industry (see for e.g. general guidelines from the European Comission [3] and review on LCA use [4]), will be adopted to carry out a sustainability assessment in line with the ISO 14040/44 framework - internationally and EU recognized guidelines for conducting LCAs consistently and transparently [5][6].

Performing a detailed and transparent LCA during the concept study phase of the WST will offer significant benefits to the astrophysics community. The methodology used can easily be transferable in a different context, for the study of a different telescope or instrument. The identification of the environmental "hotspots" of the telescope will inform design choices and guide the conception of future astrophysical infrastructures, leading by example in the design of more sustainable research infrastructures.

The required input data for the sustainability assessment will be collected at interface with WP3, WP4, WP5, WP6,and will represent the inventory data in the LCA. The inventory data encompass (see WP6.4 Appendix 1 for the detail table to be used to collect the inventory data):

- **Component name**
- **Subsystem**: part of the telescope it belongs to
- **Quantity**: number of identical units/components used.
- **Materials:** type and proportion of materials use for the component

- **Estimated mass** : estimated mass of the component
- **If mass unknown**: approximate dimensions or volume or a similar existing component/telescope used as a reference
- **Supplier/manufacturer** : company providing the component or the materials
- **Country of origin**: where the component or material is produced or shipped from.
- **Transport mode**: mode of transportation of the component to the assembly site or construction site
- **Operation phase resource use** (if applicable)
- **Maintenance or replacement info** (if applicable)

The inventory input data will be stored in Excel or CSV format. If mass data is unavailable, estimates based on component dimensions will be used. As a last alternative, if masses and dimensions are not known yet, possible extrapolation from already existing astrophysical infrastructures could be made. All the hypotheses on input data will be made available, either as a separate document or included in each input data table.

The LCA sustainability analysis will use the SimaPro Craft version 10.2 (updated March 31, 2025) [7]. SimaPro is a professional software tool used for conducting LCA studies. It enables the evaluation of environmental impacts associated with all stages of a product's life, from raw material extraction through production, use, and disposal. It provides advanced analysis of impact assessment, with uncertainty estimates and transparent results. Following are the four stages needed to carry out a LCA using SimaPro and how they will be addressed for WST.

Stage 1 - System boundaries and functional units

Definition of the processes, life cycle stages, and activities of a product system that are included in the LCA analysis. The functional unit defines the quantified function of the product system and serves as the reference for all impact calculations. In our LCA analysis, the functional unit is defined as "One wide-field spectroscopic facility with a 12-m class telescope constructed, operated, and maintained over a 50-year lifetime in Chile."

Stage 2 - Inventory data

WST Internal collection through work packages (see WP6.4 Appendix 1).

Stage 3 - LCA database for process references

Links to specific activities with geographic and temporal context - we will use Ecoinvent v3.10.1 database (Nov 19, 2024) [8], with updates when available. It is one of the most comprehensive and widely recognized LCA databases available and is based on ISO 14040/44.

Stage 4 - Impact assessment method

To quantify impacts on various indicators Careful considerations will be taken in selecting a suitable impact assessment method. Two options are currently under considerations: the ReCiPe 2016 method [9], supporting different geographical contexts, and the Environmental Footprint 3.0 method [10], developed by the European Commission's Joint Research Centre, mainly for European context but increasingly applied internationally. The input and data products from analysis results will be *made publicly available* on the WST secure open-access repository as an Excel spreadsheet (~<10MB), with separate tabs for each system (e.g., IFU, telescope structure). The data collection will include all inventory data, LCA references (Ecoinvent input for query), sources, assumptions, and any other relevant information necessary to make the results reproducible. A readme file summarize the steps taken through the analysis will be provided to support re-use and reproducibility.

2.6.5 WP6.5 Equity, Diversity, and Inclusion (EDI)

This sub package has a key role within the WST project and overall Consortium to oversee that activities are in respect of equity, diversity and inclusion (EDI). The team has been working towards the WST Code of Conduct (CoC) that was officially adopted by the WST Consortium on July 17th, 12025 [AD4].

The WP6.5 EDI team has oversite on the formation of a EDI Committee, as fair representation of the diverse community of the WST consortium, whose task will be to handle the evaluation and resolution of potential issues as they arise. The EDI Committee will be finalized through a selection process outlined in the CoC [AD4] and would be expected to be active by end of 2025.

The WP6.5 EDI team will be supporting activities of the WP6.3 Communication team, and the PW6.4 Sustainability team in statistical handling of data collected through the WST concept study such as evaluate impact of WST members travels and sustainability. No private information of the WST members will be made public, but the statistical budget and impact of travels for conferences and meetings throughout the concept study.

3. Allocation of resources

3.1. Costs for making data compliant to the FAIR principles

Current data repositories and storage systems can be used free of charge. A new website is under development. The cost for developing and managing this has been included in the WST budget as part of INAF allocation. The website will represent an open access repository.

3.2. Responsibility for data management

The formal, overall responsibility lies with the project coordinator, while each partner maintains a distributed responsibility for the data collected and generated by their efforts.

Current plan is to guarantee long term preservation for five years, using repositories and computer servers available at some of the project beneficiaries. Decisions on what data will be maintained on the long term will be made by the PO during the project 's life cycle.

4. Data security

The project beneficiaries have implemented data security and recovery procedures, including standard procedures for backups and firewalling as needed. The WST project will use and administers the coordination of trusted repositories:

1- SharePoint, under UKRI, as a secure and the WST- members restricted access only and will serve as reference site for documentation, metadata, data and products defined as sensitive as per EU Horizon agreement;
2- WST website (current URL: https://www.wstelescope.com), under INAF, will be open-access, and will serve as reference site for documentation, metadata, data and products defined as non-sensitive as per Horizon agreement.

5. Ethics

No ethics or legal issues that can have impact on data sharing have been identified.

The collection and processing of personal data will be complaint with the European General Data Protection Regulation [1].

Questionnaires dealing with personal data will be mainly aimed to engage the community in the WST Science Team. The forms will only request and include the following personal information: full name, affiliation, and email address. Informed consent will be included in the questionnaires, and the data will not be shared with third parties.

6. Other issues

EU Horizon open-access standard procedures for data management will apply to all EU and non-EU consortium members participating in the project.

References

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Section 5 - Ethics

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Appendices

WP6.4 Appendix 1

Example table created to collect the inventory data used as input for the LCA analysis.

Column	What to enter
WP ID	Work package number
Name of contact person	The name of the person to contact if more information is needed
Component name	The name or identifier of the component or assembly (e.g., "Coaxial cable")
Subsystem	The part of the telescope this component belongs to (e.g., IFU, main structure)
Quantity	Number of units/ components used
Material	Material used If multiple, list them all with % if known. If unknown, specify the dominant one
Estimated mass	Total weight of one unit in kg. If unknown, see next column
If mass unknown	Provide an approximate size or volume, or, if component/design is based on a similar component from an existing telescope/instrument, name the reference (e.g., "similar to MOSAIC detectors")
Supplier/manufacturer	Company name or internal provider (if known) with links to the website if any
Country of origin	Country where the component or material is produced or shipped from
Transport mode	Mode of transport expected (e.g., truck, air freight, sea freight)
Operation phase resource use (if applicable)	Describe any energy or resource use associated with this component during operation (e.g., continuous cooling, motors, electronics consumption). Indicate the type of resource and, if known, provide an approximate annual consumption (e.g., kWh, L/year).
Maintenance or replacement info (if applicable)	Does the component require regular maintenance, replacement, or calibration? Provide frequency (e.g., replaced every 5 years) and materials/parts involved.
Assumptions	Mention any assumptions made (e.g., to compute the mass)
Comments	Mention any other relevant information & if available, reference relevant technical documentation or sources.
Design status	Mention the state of the design, any other option considered, is this preliminary, final, need update soon?
Last update date	Date of the last design update