IRF Requirements Overview

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Contents

- Basic requirements for DL3
  - In existing requirements structure
- Error budgets - allowed IRF uncertainties
  - Work in progress
- Supported observation types/modes
  - Proposals from top-level use case process

Provision of High Level Data (DL3)

- **B-DATA-0260 High Level Data Products**:
  The high level data products to be provided for a set of observations associated with a single target include gamma-ray images, light-curves and reconstructed gamma-ray spectra. Such products, as well as the Event list and instrument response files, should be provided in FITS format where possible, or extensions to FITS where necessary.

- **B-DATA-0570 Instrument Response Information**:
  Instrument response information, providing CTA response to the required precision for the full phase-space of allowed CTA observing modes, directions and conditions, must be available to at least Privileged Users.

- **B-DATA-0580 Instrument Response Provision**:
  Instrument response functions matched to the observations, reconstruction algorithms and event cuts used for processing must be provided to the Guest Observer.

Contribution of IRFs to Uncertainties

- In general, uncertainties arising from IRFs/analysis should contribute only to a small fraction (e.g. < 1/3 contribution so <10% in quadrature) to the overall uncertainty budget (e.g. as other things are typically harder – like instrument and atmospheric models)
  (potential new level A requirement)

- For IRF and DL3 generation we have
  - **B-DATA-0460 Instrument Response Generation**:
    - *Simulation data products must be sufficient for the generation of full instrument response information*.
    - "**full**": for all appropriate instrument modes, pointing directions, target offsets and other matrix dimensions necessary to meet the required response precision
  - **B-DATA-0330 Standard Level C Analysis Pipeline Sensitivity**:
    The standard Level-C analysis pipeline must result in data products that meet the CTA (gamma-ray) performance requirements

Energy Scale and Effective Area

- **A-PERF-0260 Accuracy of Energy Scale** : < 15%
- **A-PERF-0380 Effective Area Knowledge**: < 12%

- Main contributions from the quality of the model (MC) and the IRFs

- Quality of the model: up to 10% uncertainty contribution, arising from [tentative budget]:
  - Shower simulations 3%
  - Atmospheric model uncertainties (after monitoring) 5%
  - Instrument model uncertainties 8%

- To reach 12% with 10% uncertainty from the model, uncertainties in the IRFs must be < 5%

- **A-PERF-0410 Exposure Uncertainty**: < 15%
  - (Just effective area plus livetime – dominated by area)

Knowledge of the Response

- Missing requirements on how well we need to know the energy dispersion and PSF
- Minimum
  - Systematic errors on the angular resolution, as characterised by the 68% containment radius, as a function of energy must be < X% :
  - (and similar for energy resolution)
- Maximum
  - Different numbers for different energy ranges:
    - e.g. 10% probably OK at 20 GeV and 100 TeV – but probably not at 1 TeV
  - Specify several percentiles (e.g. 95%) to ensure that tails are captured properly
- Again the IRFs would be assigned a small fraction of the overall uncertainty budget

Sketch of Observing Process

- Proposals submitted
- Ranked by a TAC
- Accepted proposals used to form a long-term schedule
- Mid-term (i.e. much shorter than AO cycle, not during the night) schedules developed at the two sites
  - Planned maintenance, calibration and investigative actions
  - Short-term schedule modified dynamically and automatically during observations
  - e.g. changing weather conditions, incoming triggers, RTA results…
- Observations are based on scheduling blocks (SBs) from a short-term schedule
  - e.g. an SB can include target changes – like wobble
- During observations, telescopes may drop-out / rejoin observations for calibration purposes, or if a ToO or problems occur
- Cameras take data while slewing (new requirement planned)
- Define “runs” for analysis purposes ***after*** data has been taken
  - i.e. all data is time-stamped / synchronised

Observing Modes: From TLUC

Under Discussion

- **Pointing_Coordinate_System**: *Ra-Dec / Alt-Az / Gal*
- **Nominal_Pointing:** pointing coordinates for the Target (*a single coordinate or a list of coordinates*)
- **Array:** *N and/or S or N or S*
- **Requested_SubArray**: (and min # tels) a set of preconfigured options, e.g.
  - Full Array
  - LST Sub-Array
  - MST Sub-Array
  - SST Sub-Array
  - Other predefined configurations (provided by the Observatory)
- **Observing strategies**: The observing strategy describes how the choice of pointing positions allows the PI to reach the *Proposal* science (through *Targets*) goals relative to scientific aspects and analysis constraints (statistics and systematic errors).
- **Array pointing:** how to coordinate the telescopes of the same sub-array. E.g. parallel (*no increase/decrease of the FOV*) or individual telescope pointing offset list (*for expert*) - optional parameter
- **Zenith_Range:** minimum and maximum allowable zenith angle during the SB
- **Precision_Pointing:** a tick box enabling highest pointing precision (low wind, low temperature gradient); the SB will not be executed unless these conditions are met - optional parameter
- **Requested_Time:** amount of observation time on the Target
- **Allowed_Time_Range(s):** Observation time and epoch and time sequences and/or constraints. Table of observing windows when the observations are allowed. For ToO observations: maximum duration of an observation, maximum time delay. For monitoring observations, frequency in day(s), minimal observation cycle per observation night.
- **Tracking mode**: How to follow the target during the observation (e.g. drift, sidereal)
- **Minimal_Sky_Quality:** Specifying atmospheric quality (transmission); the Scheduling Block will not be executed unless these conditions are met.
- **NSB_Range:** Minimum and maximum allowed NSB, mainly due to the moon; the SB will not be executed unless these conditions are met.

Conclusions

- CTA IRF needs currently poorly captured in CTA Requirements
  - Input from this group would be very much appreciated

- Overall science operations plan (with consequences for DL3/IRFs) still under discussion /development
  - Top-level use cases and a range of existing documents (mostly lacking details) as main inputs

- Hope to make major progress on both aspects before the summer

Thank you for your attention

Questions?

Provision of High Level Data (DL3)

- High Level Data to be provided to the users:
  - Event lists
  - Instrument Response Functions
  - Auxiliary data (pointing information, deadtime)

- **B-DATA-0260 High Level Data Products**:
  The high level data products to be provided for a set of observations associated with a single target include gamma-ray images, light-curves and reconstructed gamma-ray spectra. Such products, as well as the Event list and instrument response files, should be provided in FITS format where possible, or extensions to FITS where necessary.

Observing Modes - Proposal Preparation

- **B-DATA-0620 Proposal Support**:
  Tools must be developed and provided for public use, that allow the estimation of CTA performance as a function of the full allowed range of modes, pointing directions and conditions.

- Proposers have the following options:
  - Pointing coordinate system
  - Nominal Pointing
  - Array & Requested sub-array
  - Observing Strategy
  - Array Pointing
  - Zenith range
  - Precision Pointing
  - Requested Time & Allowed time range
  - Tracking Mode
  - Minimal Sky Quality and NSB range

Observing Modes - types

- Target:
  - Position of interest within the field
  - Multiple Targets from different proposals can be merged in to one set of SBs (perhaps called a ‘Project’)
- Observing Strategy:
  - Pattern of offsets from the Target
  - Will be a default (e.g. Wobble) – but can be customised (e.g. raster scan)

- Array Pointing:
  - Parallel
  - Divergent
  - Convergent

Energy Resolution

- Proposed new requirement:

- Systematic errors on the energy resolution as a function of energy well above threshold should be < 10 % :
  - A contribution of 5% from systematic uncertainties in the MC
  - *A contribution of 5% from image truncation and core localisation (?)*
  - A contribution of 5% from the IRFs and analysis

- “well-above-threshold” = a factor of two above the lowest energy at which sensitivity is required

Angular Resolution

- Proposed new requirement:

- Systematic errors on the angular resolution, as characterised by the 68% containment radius, as a function of energy must be < 10% :
  - A contribution of 5% from instrument efficiency and pixelisation
  - A contribution of 5% from systematic uncertainties in the MC
  - A contributions of 5% from the IRFs and analysis

Point Spread Function

- **A-PERF-2150 Optical PSF:**
  The telescope optics will have a negligible impact on performance as long as the optical PSF size is much smaller than the size of a camera pixel and/or the minimum angular scale on which shower information can be derived from typical images.

- Introduce A-PERF-XXX Gamma-ray (optical?) PSF

- **A-PERF-XXX PSF Dispersion**:???
  Wavelength dependent dispersion in the optical PSF over the full range of the Cherenkov spectrum (300-550nm) must not increase the optical PSF by more than 20% of its size in the core region (350-450nm).
- **A-PERF-XXX PSF Dispersion**:???
  Dispersion in the optical PSF θ_{80} must not increase its size by more than:
  - A factor of 2 due to environmental effects (wind speed, temperature)
  - A factor of 1.5 due to elevation angle (above 30^{o})
  - A factor of 3 due to off-axis angle (up to 2^{o} off-axis)
- The corresponding B-xST-0130 requirements must be simultaneously fulfilled for points 1 & 2.

Overview

- Guidelines on uncertainty budgets for IRFs

- Observing Modes for CTA:
  - The **observing mode** defines the configuration of the (sub-)array, the observing conditions and constraints for the execution of a *Target*
  - Types of observing mode
  - Parameters describing observing modes

- The ***Target*** describes the object(s), the source(s) to observe in order to study the scientific case of the Proposal, each Target having a unique sky position (called Nominal_Pointing in the Observation Mode)

Other Related Requirements

- **B-DATA-0440 Simulation Pipeline**:
  A simulation pipeline is required for CTA to characterise the response of the instrument to gamma-ray initiated cascades and to optimise the background rejection performance. This pipeline must include the Monte-Carlo (MC) simulation of electromagnetic and hadronic cascades, Cherenkov light production and propagation, telescope optics ray- tracing and detailed electronics simulation resulting in fake raw data. Event reconstruc- tion using these data must be performed in an identical way to the standard pipeline, resulting in Event list and intermediate data products in identical formats. Instrument response generation based on these outputs is the last step of the simulation pipeline.