MAX PLANCK INSTITUTE FOR RADIO ASTRONOMY

ARGOS

Conceptual Design Study

Designing a Next-Generation Radio Facility for Multi-Messenger Astronomy

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Abbreviations and Acronyms

Acronym	Description
COTS	Commodity off-the-shelf
EVN	European VLBI Network
FFT	Fast Fourier Transform
GbE	Gigabit Ethernet
GPU	Graphics processing unit
NIST	National Institute of Standards and Technology
RFSoC	Radio Frequency System on a Chip
SPEAD	Streaming Protocol for Exchange of Astronomy Data
TFR	Time Frequency Reference
UDP	User Datagram Protocol
UTC	Coordinated Universal Time
VDIF	VLBI Data Interchange Format
VLBI	Very Long Baseline Interferometry
WP	Work Package

1. Purpose and scope

The goal of the task 6.2 is to design a scalable backend system for the ARGOS telescope. The backend system take instructions from telescope control system (WP3) and processes data from the frontend (WP5), providing feedback and producing intermediate or final scientific data products It also interacts with or provide resources for the frontend, science processor (WP7) and the storage facility. A contextual view of these work packages is shown in Figure 1.

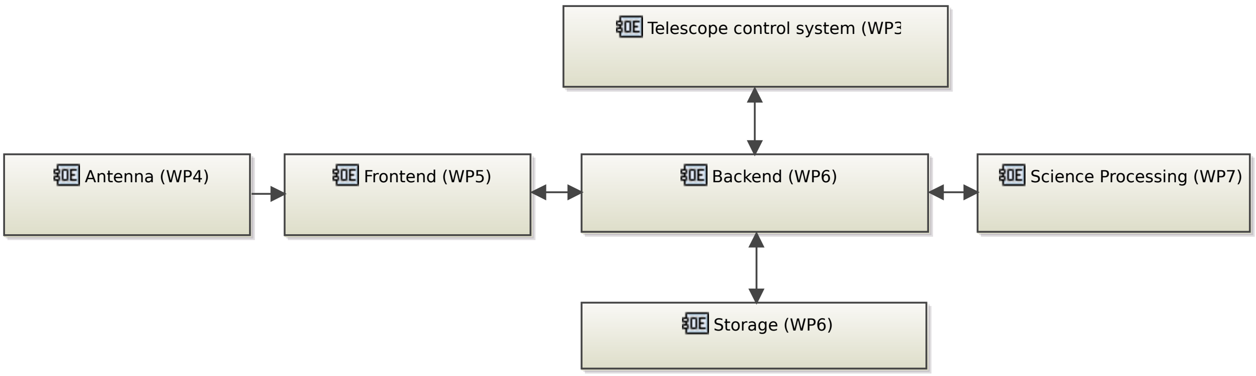

Figure 1: Scope of the work package

2. Mission

The mission of the backend system is to interpret commands from the telescope control system, process data from the frontend, and generate the data products necessary to support multiple observational modes. These modes include:

1. Transient searching
2. Pulsar timing
3. Baseband recording
4. VLBI (Very Long Baseline Interferometry)
5. Polarimetric imaging

The backend system creates and delivers these data products to the storage system or the science processor for further analysis. Specifically, it handles:

- Generation of beamformed time series data for transient searching and pulsar timing
- Recording capability for VLBI experiments and baseband data
- Generation of visibility data for imaging and calibration

This comprehensive approach ensures the backend system supports a wide range of scientific observations and data processing needs.

3. Stakeholders

The following key stakeholders are identified for the backend system:

Telescope operators: These are the people or systems that manage control of the telescope. They request actions directly or indirectly from the backend and monitor the behaviour and state of the backend during observations.

Scientists: These are the end users of the data products from the backend. In most cases data from the backend must undergo processing in subsequent systems before data is ready for scientific use.

System administrators: These are the people that manage the system administration of the backend hardware. This includes hardware configuration management and day-to-day monitoring and maintenance.

Technicians: These are the people who physically interact with the backend system on site in order to install, maintain or remove equipment.

Telescope management: These are the people managing the coordination of all systems on the telescope including day-to-day operations and future planning.

Developers: These are the people or teams that produce the software and firmware necessary for the operation of the backend system.

4. Use case

A typical use case for the backend would be the following:

1. A telescope operator schedules an observation using the telescope control system.
2. The telescope control system sends commands to the backend to initiate an observation.
3. The backend accesses the request and provisions all necessary computing resources to conduct the observation.
4. The backend configures the digitization and channelization components to process the signal from the frontend and channelised voltages data starts streaming.

At this stage there are two processing chains which may or may not be operated commensally depending on the needs of the observation:

Correlation chain:
- i. The digitised, channelised voltages are cross correlated.
- ii. The resulting visibilities are then transmitted to the science processor for imaging or calibration.

Beamforming chain:
- i. The digitised, channelised voltages are weighted and summed to form beams.
- ii. Baseband and VLBI data are stored by the storage sub system.
- iii. Voltage and detected beams are transmitted to the science processor for pulsar timing and transient searching.

In the final step, data products written to storage by the backend or produced by downstream processing in the science processor are made available to scientists for detailed analysis.

A use case diagram demonstrating the steps for missions such as imaging, generating time series and calibration is shown in Figure 2

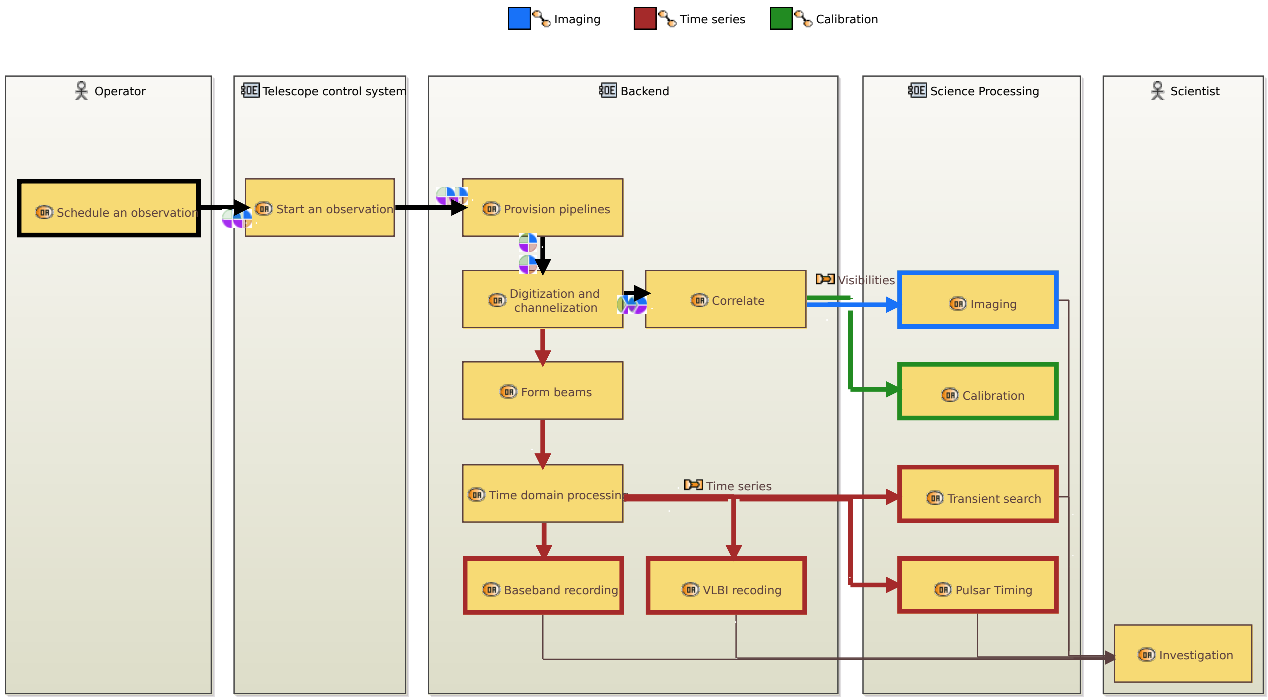

Figure 2: Use case diagram showing how missions such as imaging, generating time series and calibration are performed.

5. Logical breakdown

The ARGOS backend consists of the following logical components: Management, Time Frequency Reference (TFR), Digital Receiver (Rx), Data Processing, Storage and Data Transport. These are shown in Figure 3. Below we introduce each of these components in detail describing their purposes and responsibilities.

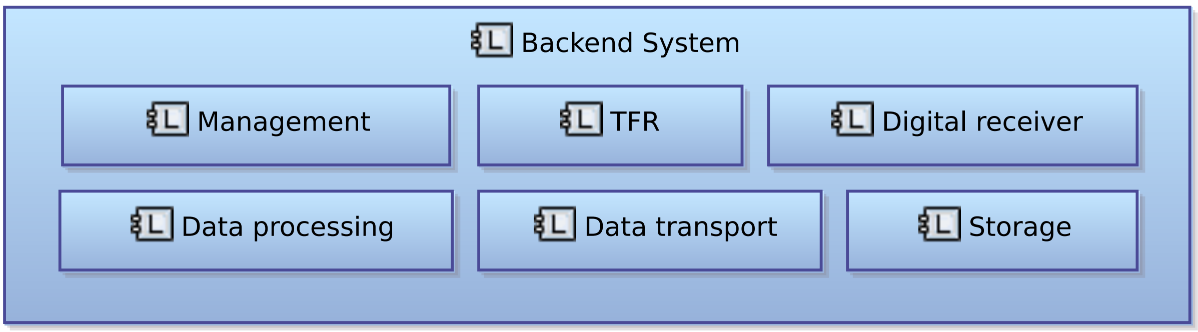

Figure 3: Logical components of the ARGOS backend

Management

The Management component shown in Figure 4 is the brain of the backend system. It is responsible for:

- communication with the telescope control system

- Acquisition of telescope metadata required for observations
- monitoring of other backend components
- management of the backend state model
- provisioning of resources for other backend components
- scheduling, dispatch and lifetime management of backend processing pipelines

The Management component is the primary point of interaction for telescope operators and system administrators.

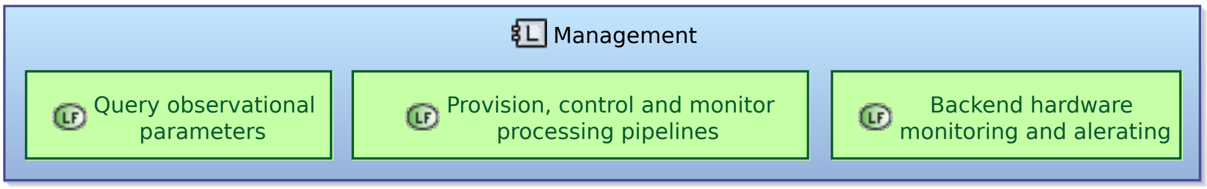

Figure 4: Management logical component

Digital receiver

The digital receiver component shown in Figure 5 is composed of several sub-components, which when taken together provide the means to accurately digitise and distribute the signals received by the ARGOS frontend while also providing the means of control for the frontend subsystem of WP5 and distribution of precise timing information through the observatory. In the following sections we break down the sub-components of the digital receiver

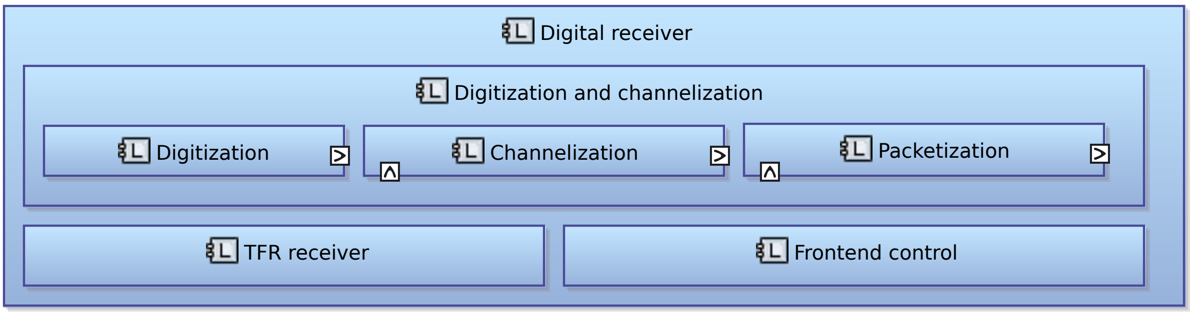

Figure 5: Digital receiver logical component

Time Frequency Reference (TFR)

The Time Frequency Reference (TFR) component (Figure 6), provides precise absolute and relative time information for the ARGOS backend. It is necessary to ensure frequency stability of the ARGOS observing band as well as accurate timestamping needed for pulsar timing experiments. The TFR component is subdivided into three further components:

GPS receiver: A component that receives GPS time information from GPS satellites. This provides the TFR component with an absolute time derived from International Atomic Time (TAI).

Frequency reference: A stable frequency reference that can output a specific frequency (e.g. 100 MHz). Could be physically realised by any sufficiently high stability clock (e.g. a Hydrogen maser or Rubidium clock). The frequency reference is also responsible for generating a 1 Pulse Per Second (PPS) signal that defines time in the observatory's reference frame. To convert between the observatory reference time and UTC(TAI), measurements from the GPS receiver must be used.

TFR transmitter: A component that distributes the observatory frequency standard and 1PPS to all downstream components that require it.

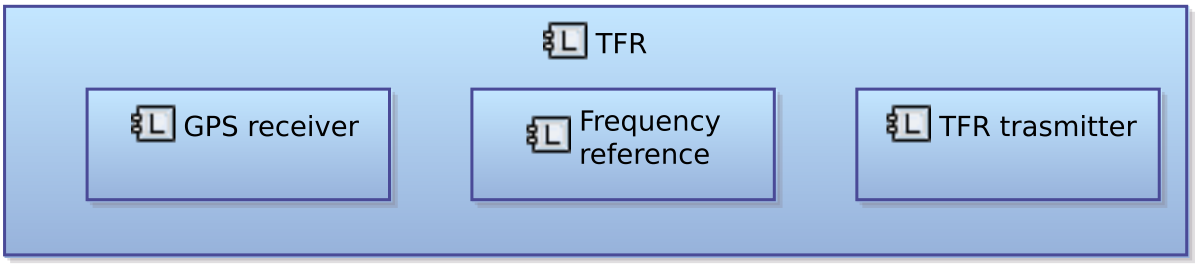

Figure 6: Time frequency reference logical component

Digitization

The digitization logical component shown in Figure 7 performs analogue-to-digital (A/D) conversion of the voltage signals from the ARGOS frontend. It receives commands from the management component to configure the A/D device and start or stop the conversion. The digitization component is also responsible for monitoring the properties of the conversion and tracking performance metrics such as number of saturated bits and the distribution of output samples (the digitiser histogram).

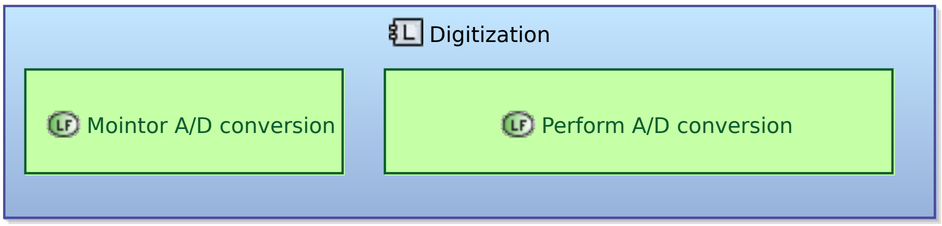

Figure 7: Digitization logical component

Channelisation

The channelisation logical component shown in Figure 8 is responsible for channelising the voltage signals from all antennas and applying geometric delay corrections. The component achieves this by:

- acquiring or generating geometric delay solutions based on the desired observation phase centre
- performing whole sample (coarse) delay correction for each antenna and polarisation channel
- performing an oversampling polyphase filter to produce oversampled channelised data
- apply the residual (fine) delay correction by multiplying the data in each frequency channel by a complex weight

The fine and coarse delay corrections applied in the channeliser may also include static instrumental delays and/or calibration weights (e.g. bandpass equalisation may be optionally applied here).

The choice of an oversampling channeliser here is driven by requirement REQ-ARGOS-BE-05 which states the need for compatibility with existing VLBI infrastructures. To satisfy this requirement by proceeding without channelisation is not an option for ARGOS due to physical constraints on how the large volume of antenna data can be distributed across processing resources. As such we choose here a mode of channelisation that is trivially invertible. This allows for the wideband time-domain signal to be reconstructed after beamforming using a synthesis filter. This data can then be digitally down converted to one or more arbitrary sub-bands for use in VLBI experiments.

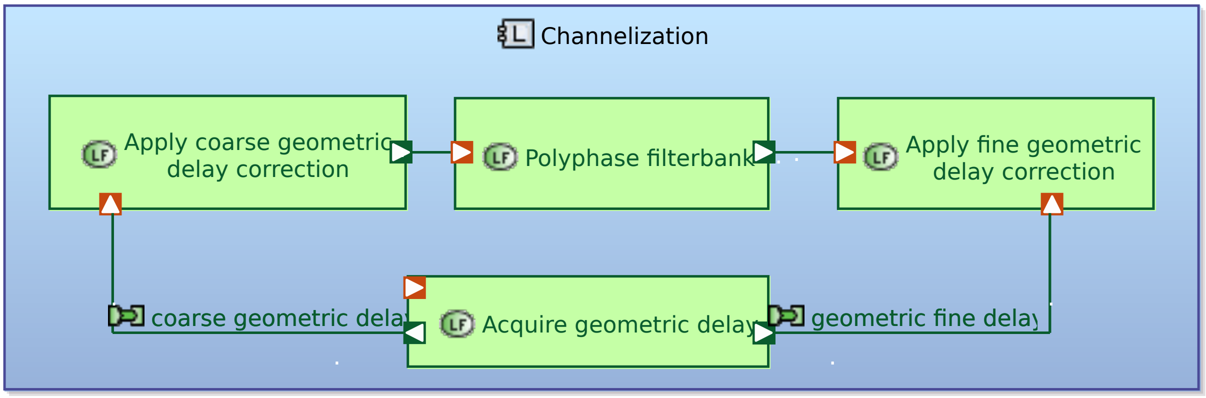

Figure 8: Channelization logical component

Packetisation

The packetisation logical component shown in Figure 9 is responsible for the conversion of oversampled channelised voltage data into Ethernet packets that can be distributed over the ARGOS data transport network. The packet format used is currently expected to be UDP with payloads conforming to the Streaming Protocol for the Exchange of Astronomical Data (SPEAD).

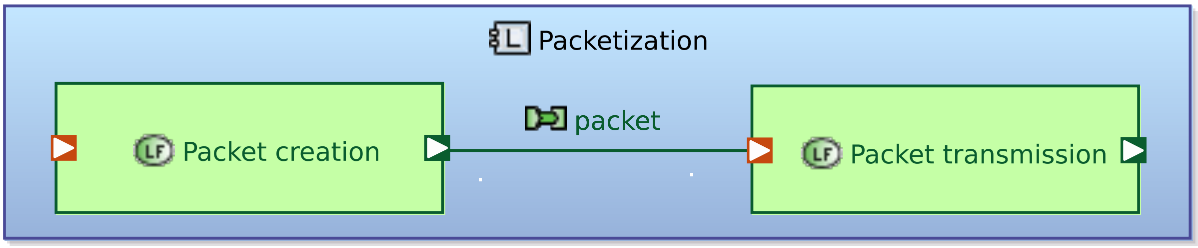

Figure 9: Packetization logical component

Data processing

The data processing logical component shown in Figure 10 is composed of multiple sub-components, which when taken together provide the principle data processing capabilities of the ARGOS telescope. Below we break down these sub-components.

hosts a beamformer to form coherent beams , a correlator to create visibilities , a time domain processor and a science processor. The beamformer also provides geometric delay for the delay correction in the digital processing chain. The product of the correlator will be transferred to the storage facility and be fetched by the science processor which hosted by the backend system but managed by WP7. The data processing servers can also provide general purpose computing services for users through virtual machines.

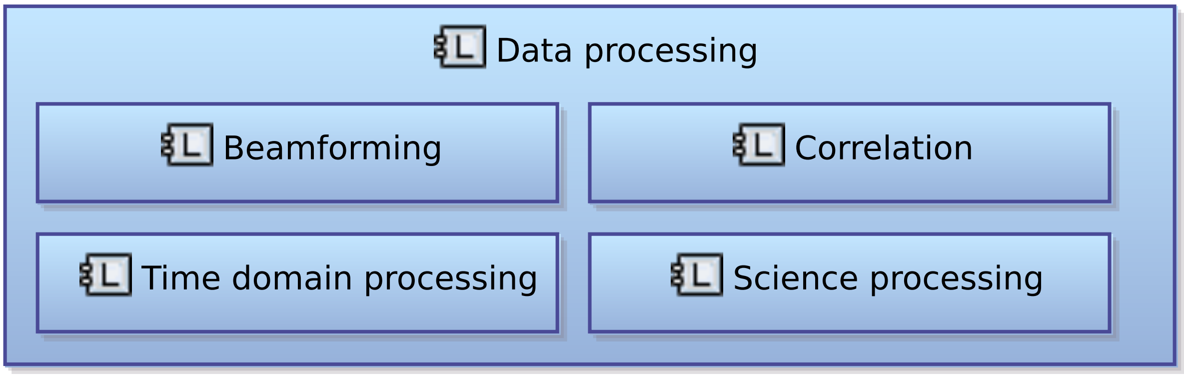

Figure 10: Data processing logical component

Beamforming

The beamforming logical component shown in Figure 11 is used to form "coherent" tied array beams out of the voltages from the digital receiver. Note that we use the terms "coherent" and "incoherent" to differentiate between beamforming using the sum of voltages from all antennas and the sum of powers from all antennas, respectively. The latter is not typically considered true beamforming as it does not rely on the phase coherent addition of the signals from all antennas and as such does not alter the directivity of the array.

The beamforming component is composed of the following logical functions:

Geometric weight generation: Based on inputs from the telescope operator, geometric delays for all desired beams must be created. Here it is expected that the generated delays will be the residual delays between the desired beam positions and the array phase centre. This is due to the delays for the array phase centre having already been corrected for in the digital receiver system upstream. As such the delays can be represented as a set of time-dependent complex-valued weights for each combination of antenna, frequency channel, polarisation and beam. It is assumed here that all geometric weights have uniform magnitude.

Apply geometric weight: The data arriving from the digital receiver must be multiplied by the weights determined in the previous function.

Apply instrumental weight: Any additional instrument dependent complex gain corrections may also be accounted for via multiplication of the incoming data by a set of complex gains for each combination of antenna, frequency channel and polarisation. The complex gains used here are generated during calibration cycles in the science processor. These weights may have arbitrary amplitude.

Form an incoherent beam: Prior to application of geometric weights but post application of instrumental weights, an incoherent beam is formed. Here the Stokes parameters of each antenna are (using the Detect Stokes logical function) and summed together.

Form coherent beams: After the application of instrumental weights, a coherent beam is formed for each set of beam-dependent geometric weights via the summing of the weighted voltages across all antennas.

Detect Stokes: Given antenna or beam voltages, this function computes the total power, linear and circular polarisation as the Stokes vectors I, Q, U and V. For incoherent beamforming this is used prior to the summation of the antennas and for coherent beamforming it is used after the summation of the antenna voltages. For certain observation types only a single Stokes parameter is required and so this function should output I, Q, U, V or IQUV depending on the use case. Beams intended for science cases requiring voltages data (e.g. VLBI) are not detected.

Integrate: All detected data can be optionally integrated in time and/or frequency to reach the desired resolutions for the given experment.

The above functions lead to the possibility of different types of beams being created in the beamformer. For example time-integrated, Stokes I, V or IQUV detected beams may be used for fast-transient searching experiments while voltage beams may be used for VLBI and downstream processing requiring coherent dedispersion or coherent Faraday derotation.

An important logical function currently missing from this component is **synthesis filtering**. Synthesis filtering allows for the effects of oversampling on antenna or beam voltages to be undone providing neighbouring frequency channels with strong spectral isolation. Additionally this is the first step in inverting the polyphase filterbank to convert the data back to unchannelised wide-band voltages necessary for full compatibility with existing VLBI experiments. The reason this is not shown in Figure 11 or 12 is due to the uncertainty in where it belongs in the design. For instance, it is *necessary* to perform synthesis filtering prior to correlation and the formation of the incoherent beam, but for the voltage beams used for pulsar timing and VLBI it is *computationally preferable* that synthesis filtering happens after beamforming (as for these beam types there are expected to be many fewer beams than antennas and thus less data to operate on). As synthesis filtering is strictly needed before correlation it appropriate to consider it its own logical subcomponent of the data processing component. The results of pending prototyping efforts will inform the location of synthesis filtering in future updates to the ARGOS backend design.

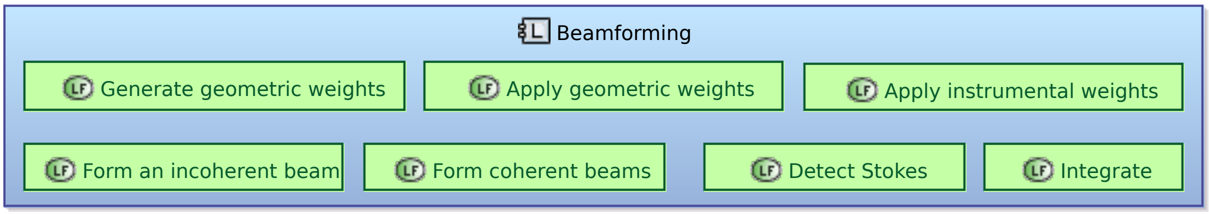

Figure 11: Beamforming logical component

Correlation

The correlation component shown in Figure 12 performs visibility generation for the ARGOS backend. It is responsible for:

- generating the mapping of antennas to baselines
- performing cross correlation of the data streams from each antenna
- integrating the resulting visibilities up to some telescope operator defined interval

As noted above, it is necessary to perform synthesis filtering prior to correlation.

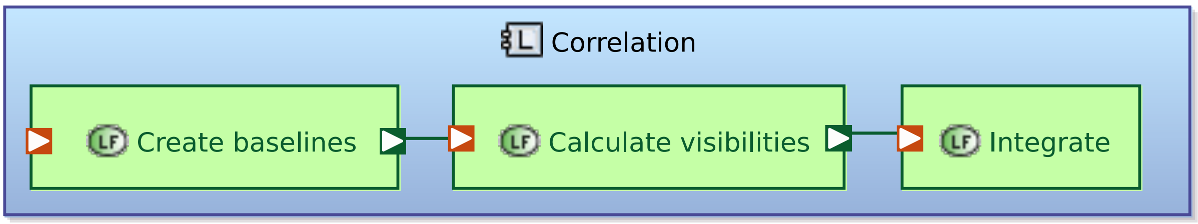

Figure 12: Correlation logical component

Time domain processing

The time domain processing logical component shown in Figure 13 is composed of multiple logical functions that map to specific formatting options for beams produced in the beamformer. The following functions are required:

Filterbank recorder: This function takes Stokes I, Q, U, V or IQUV coherent or incoherent beams and formats them in a standard format for time-domain search-time products (e.g. Sigproc filterbank or PSRFITS formats). Such data products are intended for offline fast-transient experiments.

VLBI recorder: This function takes coherent voltage beams and perform **polyphase filter inversion** to convert the data into a wide-band time domain stream. This is then processed in a **digital down converter** which baseband mixes and resamples the data to specified VLBI bands. The data are then **rescaled** to 2-bit based on specific level settings defined as part of the VLBI Data Interchange Format (VDIF) specification. The data are then **packetised** in VDIF format before being written to storage. Such data are suitable for streaming over a network to support eVLBI experiments.

Baseband recorder: The baseband recorder function takes voltage streams from either antennas or beams that may or may not have undergone digital down conversion and writes them to storage. The purpose of the baseband recorder is to provide the means to access the rawest data that is flowing through the backend. While this functionality may be used for specialist experiments (e.g. scintillometry, cosmic ray air burst detection or pulsar VLBI) its primary use case is debugging the telescope operation. The baseband recorder offers the possibility to tap into the raw data stream of any antenna or beam at different stages of processing for detailed offline analysis. Data should be recorded in a simple file format suitable for very large data (e.g. DADA format).

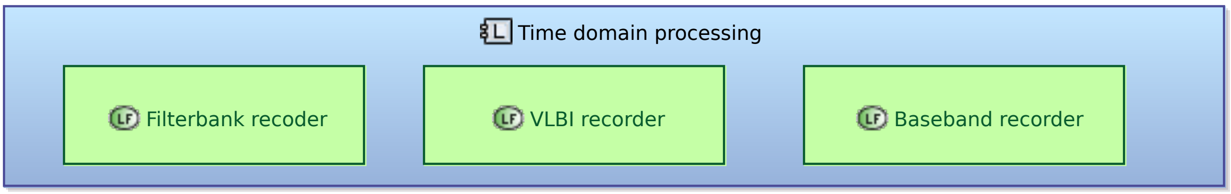

Figure 13: Time domain processing logical component

Science processing

While the science processing system is considered a logical component of the ARGOS backend, it is developed and managed by WP7. The reason to include it here due to its tight coupling with the rest of the backend and the fact that in the physical design of the backend the science processor is expected to share processing resources with the beamformer and correlator systems.

The science processor component computes and provides calibration solutions as well as performing imaging of visibilities generated by the correlator and pulsar timing analysis of coherent voltage beams from the beamformer.

Detailed discussion of the the internals of the science processing component is out of scope for this document.

Storage

The storage component is responsible for providing a unified interface for the storing and retrieval of data withing the ARGOS backend. The storage system is required to be accessible by the science processor (WP7) and the archiving and alerting system (WP8).

The storage component is also where the logical responsibility for the **transient buffer** (REQ-ARGOS-BE-30) lies. Here the storage system will provide the means to buffer a large volume of oversampled channelised voltages from the digital receiver system. Upon receipt of a suitable trigger up to 300 ms worth of voltage data will be written to long-term storage. A similar such transient buffer is in use at MeerKAT and a publication detailing its design is in preparation (Rajwade et al, in prep).

Data transport

The data transport component is responsible for the distribution of all non-storage data products in the ARGOS backend. The largest such product is the oversampled channelised voltage stream from the antennas which must be distributed through the backend. Additionally this component handles transfer of beams and visibility data between physical components of the backend.

6. Physical breakdown

Figure 14 shows the physical breakdown of the backend design together with a possible functional to physical mapping. Each physical component is described in greater detail below:

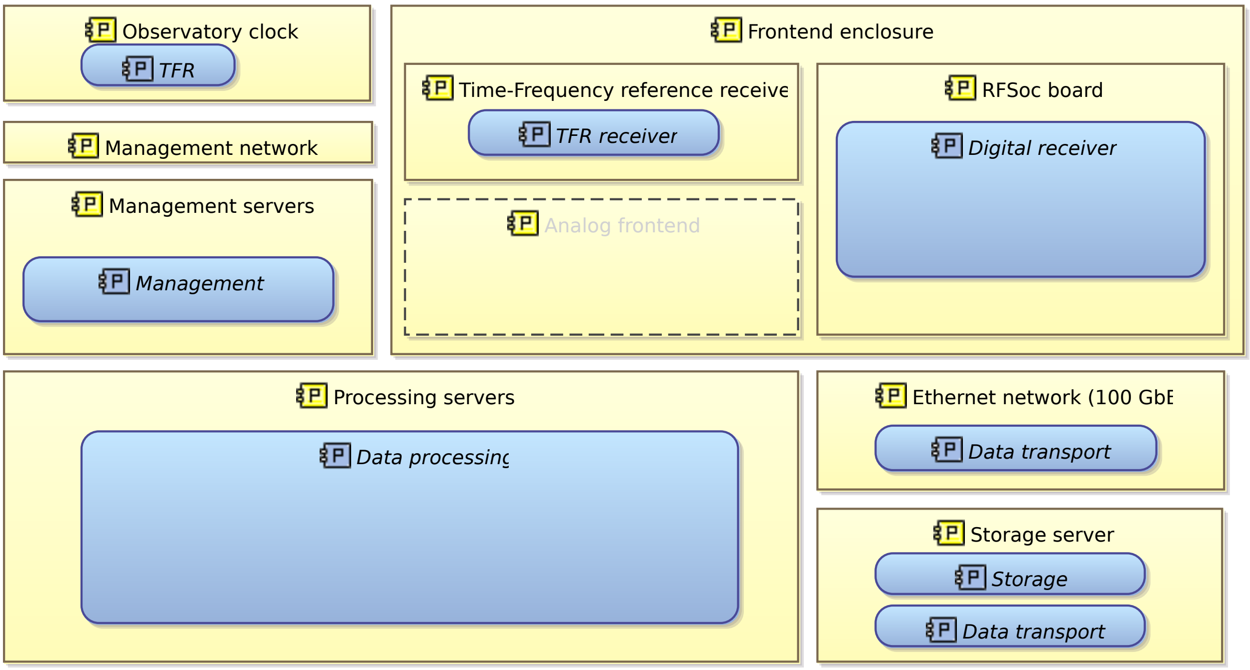

Figure 14: Physical component

Observatory clock: The observatory clock is the physical combination of a hydrogen maser and one ore more GPS receiver with a time distribution unit for transmitting a 1PPS signal and a100 MHz frequency reference to the digital receiver systems on each ARGOS antennas. It is the physical realisation of the logical TFR component.

Management network: The management network is a set 10 GbE (TBD) networks that provide the necessary control and monitoring access to all networked backend components. The management network likely consists of two logical networks, a control network and an out-of-band management network for accessing IPMI/BMI interfaces of servers and switches in the backend.

Management servers: This set of COTS servers provides the infrastructure for all control and monitoring services required in the backend as well as for any further services such as databases required for operation of the backend. These severs should have sufficient resources to act as a virtual machine farm on which services can be provisioned. Each server will have a high-speed connection to the storage servers.

Processing servers: This set of COTS servers provides the processing capability required for operation of all logical data processing functions. Each server is equipped with GPU accelerators and high-speed network interfaces for connecting to the data transport network and storage systems.

Frontend enclosure: The frontend enclosure is a physical component of WP5 which hosts the digital receiver system of the backend. It is an RFI shielded enclosure that is physically mounted on the antenna behind the feed. It is composed of multiple compartments hosting components of the frontend and backend systems. For the backend system, the frontend enclosure hosts two physical components, a TFR receiver system that acquires 1PPS and 100 MHz signals from an LC-duplex optic fibre connection an a FPGA digitiser board. Current prototyping efforts use an RFSoC4x2 evaluation board here which implements all the required functionality of the digital receiver component.

Ethernet network: This high-speed Ethernet network provides the physical realisation of the data transport component. Simulations suggest that this could be composed of as few as 10 x 800 GbE network switches in a modified folded Clos topology.

Storage servers: This set of COTS storage servers provide the necessary hard drive or solid state storage for implementing the logical storage component. These servers will be networked either through the Ethernet network used for data transport or through a separate dedicated storage network.

7. Data flow

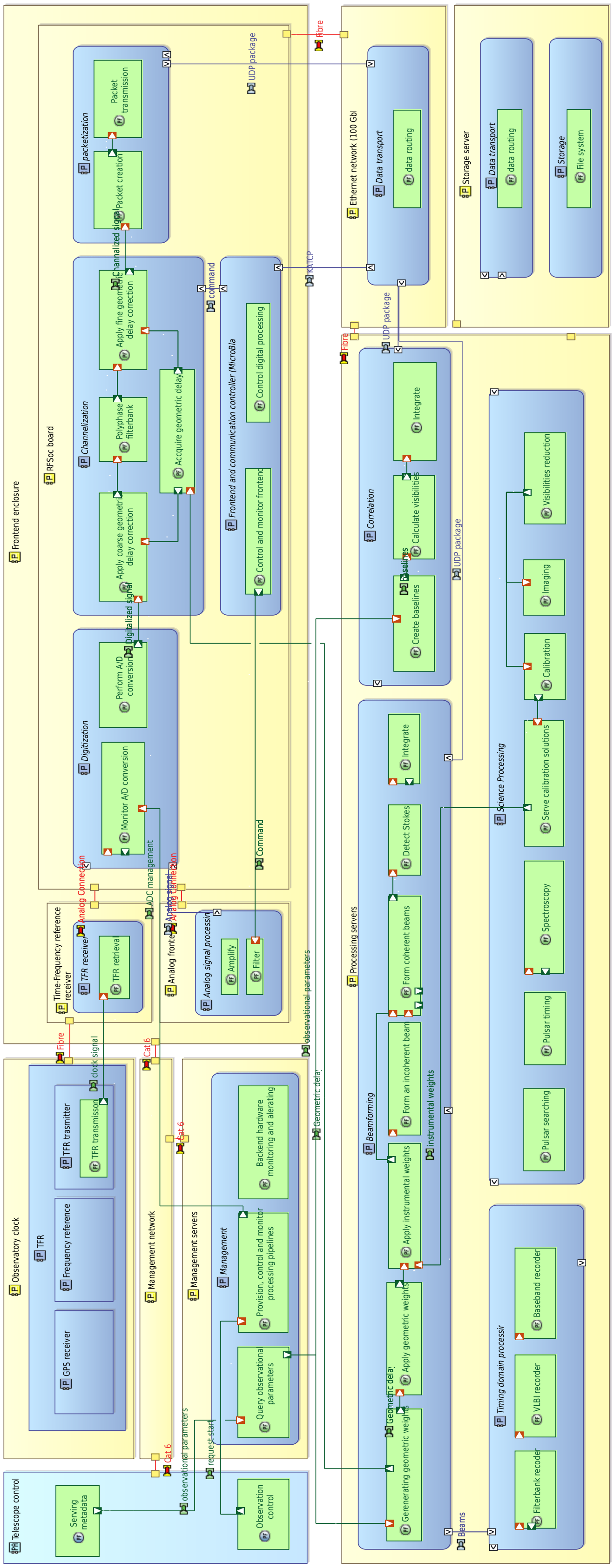

Figure 15 shows the data flow in the backend mapped to both logical and physical components.

8. Compliance matrix

Below we include the requirement compliance matrix for the above design.

1 Requirement ID	Description	Design
REQ-ARGOS-BE-01	The ARGOS backend shall have a digitized bandwidth of 2 GHz covering the RF band 1-3 GHz in dual polarization.	• An RFSoC board shall be used to provides an ADC with four channels. • Each polarization uses two channels with 1 GHz bandwidth respectively. • The bandwidth is archived via direct sampling.
REQ-ARGOS-BE-02	The ARGOS backend shall perform RFI mitigation such as to limit the impact of interference on final data products to no more than 10% of the thermal noise of the array.	Currently no explicit component in the design to satisfy this requirement.
REQ-ARGOS-BE-03	The ARGOS backend shall perform correlation, beamforming, pulsar folding, and VLBI recording over its entire effective bandwidth in both polarisations in real time.	• A GPU correlator shall be implemented. • A GPU beamformer shall be implemented. • A VLBI formatter component shall be implemented.
REQ-ARGOS-BE-04	The ARGOS backend shall apply delay solutions to the antenna voltages in real time to enable continuous tracking of single targets and/or celestial positions at between 0 and 20 times the sidereal rate up to 85 degrees elevation.	• The weight generator inside the beamformer shall produce weights that shall be applied to the voltage stream. • Weight updates shall be accurate and fast enough to perform delay correction for real time tracking.
REQ-ARGOS-BE-05	The ARGOS backend shall be EVN compatible	• The backend system shall have a VLBI mode that accepts the EVN configuration. • The beamformer shall provide compatible VLBI product.
REQ-ARGOS-BE-06	The ARGOS backend shall provide the following observational modes: pulsar folding with coherent dedispersion, correlation with integration, single burst transient search, frequency resolved integrated Stokes-I recording and VLBI recording.	• The time domain processor shall provide beamformed data products suitable for pulsar folding and single burst transient search. • The time domain processor shall provide VLBI data recording capability. • The correlator shall perform correlation with integration.
REQ-ARGOS-BE-07	The ARGOS backend shall provide a single burst transient search mode that runs simultaneously with other observation modes.	The beamformer and correlator shall be operational commensally.
REQ-ARGOS-BE-08	The ARGOS backend shall synthesize in real time at least sixteen full-stokes coherent tied-array beams using all available elements of the array.	The beamformer of the ARGOS backend shall provide weights that correct the delay for all available elements and form at least sixteen full-stokes beams in real time. (also see REQ-ARGOS-BE-04)
REQ-ARGOS-BE-09	The ARGOS backend shall ensure that all time-domain products have a fractional error in absolute flux ($\Delta F/F$) measured against an established celestial flux standard,	The ARGOS backend shall use sufficient quantization so that the integrity of the signal is preserved.

	better than 2%.	
REQ-ARGOS-BE-10	The ARGOS backend shall shall not incur fractional errors in polarization degree and polarization angle greater than 1% for all time-domain products.	The ARGOS backend shall use sufficient quantization so that the integrity of the signal is preserved during digital data processing.
REQ-ARGOS-BE-11	The ARGOS backend shall provide real-time coherent de-dispersion capability for sources with dispersion measures up to 1000 pc cm^3.	The time domain processor of the ARGOS backend shall integrate real time coherent de-dispersion pipeline that has the capability de-disperse sources with dispersion measures up to 1000 pc cm^3.
REQ-ARGOS-BE-12	The ARGOS backend shall provide real-time pulsar folding for at least one tied-array beam per subarray.	The science processor of the ARGOS backend shall integrate real time pulsar folding pipeline
REQ-ARGOS-BE-13	The ARGOS backend shall produce full-Stokes coherently de-dispersed pulse profiles with a frequency resolution of 20 kHz and a time resolution not coarser than 1 μs.	The ARGOS backend shall produce voltage beams and implement a pipeline to coherently de-disperse the data then create full-stokes pulsar profiles with a frequency resolution of 20 kHz and a time resolution not coarser than 1 μs.
REQ-ARGOS-BE-14	The ARGOS backend shall provide an observatory clock with a absolute timing accuracy better than 10 ns over 10 years with respect to UTC(NIST)	The ARGOS backend shall provide an observatory clock with a absolute timing accuracy better than 10 ns over 10 years with respect to UTC(NIST)
REQ-ARGOS-BE-15	The ARGOS backend shall provide an observatory clock with an frequency stability of better than 10^-14 over 4 hours.	The ARGOS backend shall provide an observatory clock with an frequency stability of better than 10^-14 over 4 hours.
REQ-ARGOS-BE-16	The ARGOS backend pulsar folding pipeline shall not degrade the SNR response of the array by more than 2%.	The ARGOS backend pulsar folding pipeline shall not introduce errors in digital data processing.
REQ-ARGOS-BE-17	The ARGOS backend shall provide full-Stokes pulsar pulse profiles with frequency resolution no larger than 50 MHz for pulsar timing.	The ARGOS backend shall implement pulsar folding pipelines that output full-Stokes pulsar pulse profile with frequency resolution no larger than 50 MHz for pulsar timing.
REQ-ARGOS-BE-18	The ARGOS backend shall perform pulsar folding observations in up to four subarrays simultaneously.	The ARGOS backend shall implement pulsar folding pipelines to perform pulsar folding for each subarray. These pipelines shall work independently and simultaneously.
REQ-ARGOS-BE-19	The ARGOS backend shall perform pulsar folding for each subarray. The concurrent total number of pulsar folding beams across all subarrays shall not be less than 16.	The ARGOS backend shall implement pulsar folding pipelines to perform pulsar folding for each subarray. The ARGOS backend shall implement multi-beam observations and the number of beam shall not be less than 16.
REQ-ARGOS-BE-20	The ARGOS backend shall correlate voltage signals of all antenna pairs in the array in real time.	The ARGOS backend shall implement and integrate a correlator that correlate voltage signals of all antenna pairs in the array in real time.
REQ-ARGOS-BE-21	The ARGOS backend shall produce visibilities with an absolute photometric accuracy of 5%.	The ARGOS backend shall implement a correlator to produce visibilities with an absolute photometric accuracy of 5%.
REQ-ARGOS-BE-22	The ARGOS backend shall not degrade the polarisation response of the array by more than 2% when compared to an adopted celestial polarisation standard across the entire FoV of the primary beam.	The ARGOS backend shall use sufficient quantization so that the integrity of the signal is preserved during digital data processing.
REQ-ARGOS-BE-23	The ARGOS backend shall provide visibilities with a brightness dynamic range of not less than 40 dB at 25	The ARGOS backend shall implement a correlator to produce visibilities for WP7.

	arcsecond spatial and 1 MHz frequency resolution.	
REQ-ARGOS-BE-24	The ARGOS backend shall provide visibilities with a polarisation dynamic range of not less than 30 dB at 25 arcsecond spatial and 1 MHz frequency resolution.	Same as above
REQ-ARGOS-BE-25	The ARGOS backend shall correlate the voltage signals from all antennas with a minimum visibility averaging time not greater than 1 second.	Same as above
REQ-ARGOS-BE-26	The ARGOS backend shall switch between imaging and time-domain modes in less than 30 seconds.	The ARGOS backend shall switch between imaging and time-domain modes in less than 30 seconds.
REQ-ARGOS-BE-26	The ARGOS backend shall independently (per subarray) correlate the antenna voltages from up to 4 subarrays simultaneously.	The ARGOS backend shall implement a correlator to independently (per subarray) correlate the antenna voltages from up to 4 subarrays simultaneously.
REQ-ARGOS-BE-27	The ARGOS backend shall provide a real-time tied-array beam mode for single burst transient searches over its entire half maximum power beam width.	The ARGOS backend shall generate geometric correction weights to form tied-array beam in real time for single burst transient searches over its entire half maximum power beam width.
REQ-ARGOS-BE-28	The ARGOS backend shall provide a real-time de-dispersion and transient search mode, for sources with dispersion measures up to 3000 pc cm^3	The ARGOS backend shall integrate a real-time de-dispersion and transient search mode in collaboration with WP7, for sources with dispersion measures up to 3000 pc cm^3.
REQ-ARGOS-BE-29	The ARGOS backend shall produce transient candidates within no more than 1 minute of latency compared to real time with S/N, DM and spectral information.	The ARGOS backend shall produce search data for WP7 to perform transient search.
REQ-ARGOS-BE-30	The ARGOS backend shall provide a transient buffer that can buffer and record 300 ms of raw voltages from all receiving elements for a minimum of 10 transient bursts.	The ARGOS backend shall implement a transient buffer with solid state drives that can buffer and record 300 ms of raw voltages from all receiving elements for a minimum of 10 transient bursts.
REQ-ARGOS-BE-31	The ARGOS backend shall have no more than 10% SNR loss compared to ideal matched filtering when searching for transients of minimum widths of 0.1 ms between DMs 0 and 3000 pc/cm-3	The ARGOS backend shall use sufficient quantization so that the integrity of the signal is preserved during digital data processing.
REQ-ARGOS-BE-32	The ARGOS backend shall record frequency-resolved, Stokes-I time series with a minimum frequency resolution no greater than 250 kHz and minimum time resolution no greater than 30 µsec, for a minimum of 16 beams.	The ARGOS backend shall produce frequency-resolved, Stokes-I time series product and output to storage with a minimum frequency resolution no greater than 250 kHz and minimum time resolution no greater than 30 µsec, for a minimum of 16 beams.