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Client : NRF (National Research Foundation)
Project : MeerKAT
Type : Interface Control Document

PULSAR TIMING USER SUPPLIED EQUIPMENT

TO

CONTROL AND MONITORING ICD

Document number M0000-0000-034
Revision ..... E
Classification ..... Commercial in Confidence
Author ..... C Gumede, F Joubert
Date ..... 15 December 2015

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DOCUMENT APPROVAL

	Name	Designation	Affiliation	Signature /Date
Submitted by	C. Gumede	Interfaces SE	SKA SA	
Accepted by	PTUSER	PTUSE	TBD	
Accepted by	R. Brederode	CAM Manager	SKA SA	
Approved by	T. Abbott	System Engineer	SKA SA	

DOCUMENT HISTORY

Revision	Date Of Issue	ECN Number	Comments
A	2015/09/30	N/A	Initial Version
B	2015/10/29	N/A	Revised after discussion after first review
C	2015/11/17	N/A	Update after meetings with CAM and PTUSE
D	2015/12/01	N/A	Update after meetings with CAM team
E	2015/12/15	N/A	Issue for external review

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DOCUMENT SOFTWARE

	Package	Version	Filename
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COMPANY DETAILS

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LIST OF FIGURES

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LIST OF ABBREVIATIONS

FTP	File Transfer protocol
GbE	Gigabit ethernet
MeerKAT	A Radio Telescope Array located in the Karoo
KATCP	KAT Communication Protocol
ICD	Interface Control Document
IP	Internet Protocol
KAT7	7 Dish System
CBF	Correlator Beamformer
CAM	Control and Monitoring
LRU	Line Replacement Unit
CMC	Correlator Master Controller
PBS	Product Breakdown Structure
POP	Post Office Protocol
Pub/Sub	Publish-Subscribe design pattern
PTUSE	Pulsar timing user supplied equipment
SMTP	Simple Mail Transfer Protocol
SNR	Signal-to-Noise Ratio
TCP	Transmission Control Protocol
ToR	Top of the Rack
UDP	User Datagram Protocol
USE	User Supplied Equipment

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1. Introduction and Scope

1.1. Identification

This document describes the control and monitoring interface I.T.CM.8 between the Pulsar Timing Monitoring User Supplied Equipment (PTUSE) and the Control and Monitoring Subsystem (CAM) of the MeerKAT Telescope Segment. This interface uses two different protocols i.e. KATCP and Pub/Sub.

KATCP is a communication protocol which is used for the control and monitoring of the telescope equipment. The control system of the telescope does not operate on low latency basis instead; time critical commands are sent out well in advance and are scheduled by small real-time components close to the limited number of elements requiring such control. This makes it possible to use computer systems running conventional operating systems that communicate using common, non-deterministic interconnects and protocol. This made it possible to select TCP/IP over Ethernet for transport: these are well-established, pervasive and inexpensive lower communications layers.

KATCP is running on top of the TCP/IP and borrows from well established, classical Internet protocols such as SMTP, FTP and POP in that it an application protocol which is easily readable by humans; each line of text is a protocol. CAM subsystem uses KATCP to command other subsystems and receive status of the status from these subsystems.

Pub/Sub is communication design pattern used by USE to subscribe (by using a python client, provided by CAM) to metadata which is provided by CAM subsystem

1.2. Purpose of the document

This ICD describes specifics of the two protocols KATCP [6] and Pub/Sub as it is applied to the PTUSE-CAM interface for the MeerKAT project. In this interface document, PTUSE is a KATCP server and CAM is a KATCP client.

KATCP based functional interface provided by the MeerKAT CAM to monitor selected sensors of the PTUSE.

Pub/Sup based functional interface is provided by MeerKAT CAM to allow other subsystems including PTUSE to subscribe to metadata.

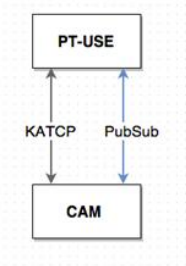

Figure 1: Interfaces layout

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The interfaces between CAM and PTUSE include the following:

a) PTUSE sensors that CAM is required to monitor
b) PTUSE commands that CAM will execute
c) Metadata subscription by PTUSE

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2. APPLICABLE AND REFERENCE DOCUMENTS

2.1. Applicable Documents

The following documents are applicable to the extent stated herein. In the event of conflict between the contents of the applicable documents and this document, the applicable documents shall take precedence.

[1] **TIA/EIA-568** Commercial Building Telecommunications Standard

[2] **INF-8077i** 10 Gigabit Small Form Factor Pluggable Module

[3] **IEEE Std 802.3-2012** IEEE Standard for Ethernet

[4] **IETF RFC 791** Internet Protocol

[5] **IETF RFC 782** Transmission Control Protocol (TCP)

[6] R. Crida, T. Bennett, S. Cross, L. v. d. Heever, N. Marais and M. Welz, **NRF-KAT7-6.0-IFCE-002**, Guidelines for Communication with Devices

2.2. Reference Documents

The following documents are referenced in this document. In the event of conflict between the contents of the referenced documents and this document, this document shall take precedence:

[7] L. van den Heveer, M1000-0001-004 Rev B, User Supplied Equipment – CAM Interface Control Document, 30 July 2013

[8] L vd Heever, P Swart, T Alberts and R Renil, M1500-0000-000, MeerKAT Control and Monitoring Requirement Specification.

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3. INTERFACE REQUIREMENT & DEFINITION

3.1. Interface Identification

This document specifies the details of the functional interface I.TE.CM.8 between the Pulsar Timing Monitoring User Supplied Equipment (PTUSE) and the Control and Monitoring CAM subsystem (M1500).

3.2. Interface Boundary of Responsibility

Figure 2 shows the boundaries of responsibility of this interface.

CAM subsystem is responsible for implementing the KATCP client and PTUSE is responsible for implementing the KATCP server.

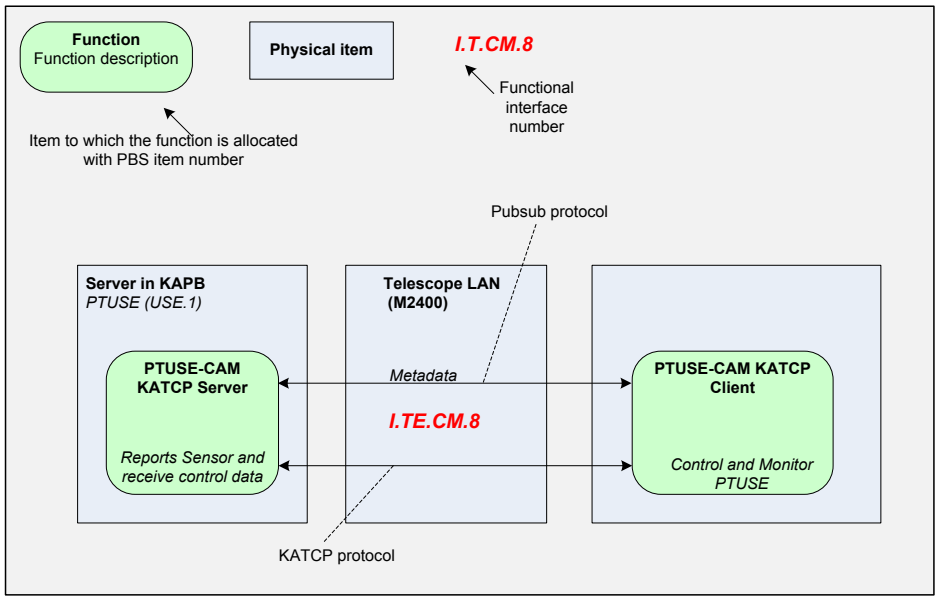

Figure 2: Boundary of responsibility on the interface

3.3. Interface Requirements

The following are the CAM subsystem level requirements referenced from CORE database which will be fulfilled by the implementation of this interface.

[R.CM.FC.C.20] When a CBF sub-division in the Pulsar Timing mode, CAM shall react to an external trigger from the user supplied pulsar timing equipment, as per [7] by terminating the current executing scheduling block and starting the next scheduling block in that sub-array.

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[R.CM.FC.C.22] For each CBF sub-division (in the Pulsar Timing mode), the CAM shall stop the currently executing SB and transition to the next scheduling block when receiving the external trigger to move to the next pulsar.

The following requirements are derived from the system level requirements above:

3.3.1. KATCP Interface Requirements

Req. ID	Name & Description
IR.T.PTUSE-CAM.1	**KATCP protocol for communication** The PTUSE and the CAM shall both implement the KATCP version 5 protocol.
IR.T.PTUSE-CAM.2	**PTUSE as KATCP server host** The PTUSE shall be the KATCP server host and shall implement the required server functionality as described in the KATCP Guidelines, rev 5.
IR.T.PTUSE-CAM.3	**CAM as KATCP client** The CAM shall be the KATCP client and shall implement the required client functionality as described in the KATCP Guidelines, rev 5.
IR.T.PTUSE-CAM.4	The CAM shall connect to PTUSE and implement synchronisation handshaking as per KATCP Guidelines, rev 5 to synchronise with the PTUSE server.
IR.T.PTUSE-CAM.5	The CAM shall request to halt the PTUSE via standard KATCP request and PTUSE shall halt all PTUSE devices.
IR.T.PTUSE-CAM.6	The CAM shall request to restart the PTUSE via standard KATCP request and PTUSE shall restart all PTUSE devices.
IR.T.PTUSE-CAM.7	The CAM shall request to configure PTUSE.
IR.T.PTUSE-CAM.8	The PTUSE shall send remote logging to CAM as per KATCP Guidelines, rev 5 (logging is archived but not monitored by CAM).
IR.T.PTUSE-CAM.9	The PTUSE shall expose to CAM a PTUSE device status sensor.
IR.T.PTUSE-CAM.10	The PTUSE shall make a SNR sensor available to CAM.
IR.T.PTUSE-CAM.11	The PTUSE shall make Beamformer gain sensor available to CAM.

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3.3.2. Metadata interface Requirements

Req. ID	Name & Description
IR.T.PTUSE-CAM.12	The PTUSE shall subscribe to CAM for metadata with an IP address specified in the KATCP configuration requests.
IR.T.PTUSE-CAM.13	The metadata shall contain frequency band, subarrays, antennas, script parameters, etc.
IR.T.PTUSE-CAM.14	The metadata exchange will be through a CAM Pub/Sub mechanism.

3.4. Interface descriptions

3.4.1. KATCP Interface description

The interface is based on message based client/server communication between a KATCP client and a KATCP server. The KATCP server is implemented by the item being monitored and controlled (in this case the PTUSE). The KATCP client is the controlling item (in this case the CAM).

The specific version of KATCP that will be implemented is 5.0 [6].

The interface requirements as specified in section 3 are used to derive the KATCP message details described in the following sections.

3.4.2. Metadata Interface description

The full detail of the CAM Pub/Sub mechanism is still TBD but will most likely use JSONRPC over Websockets. The metadata updates will be batched (between half a second to 1s).

CAM will provide PTUSE with a Python library that abstract all protocol details away.

3.5. Interface Definition

The functional interface is described in terms of Layers 1, 2, 3, 4 and 7 of the OSI model.

3.5.1. Physical Layer

The physical interconnect between the PTUSE and CAM is via the Telescope LAN.

The PTUSE has ToR switch which will connects to the Telescope LAN network. The ToR switch connects to each of the LRUs making up the PTUSE subsystem.

a) Each of those physical connections of the devices shall use 1000BASE-T (RJ45) [1] ports of the ToR switch.
b) The connection [I.T.C.F.18] between ToR switch in PTUSE rack and the Telescope LAN network shall be 10GbE port.
c) The physical connection [I.T.C.F.7] between CAM and the Telescope LAN switches shall be SFP+ 10GbE ports [2].

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3.5.2. Data Link Layer

The data link layer of the PTUSE-Telescope LAN interface shall be compliant with 1GbE Ethernet [3].

The data link layer of the CAM-Telescope LAN interface shall be compliant with 10GbE Ethernet [3].

3.5.3. Network Layer

The network layer shall be compliant with Internet Protocol (IP) Version 4 (as described in IETF RFC 791 [4])

3.5.4. Transport Layer

The transport layer of this interface shall be compliant with TCP/IP protocol (as described in IETF RFC 782 [5]).

3.5.5. KATCP Application Layer

The application layer shall be compliant with KATCP [6] and Pub/Sub.

3.5.5.1. Messages

Error! Reference source not found. illustrates the flow of the different KATCP messages types between the interfacing components. The KATCP message types are identified and described in [6].

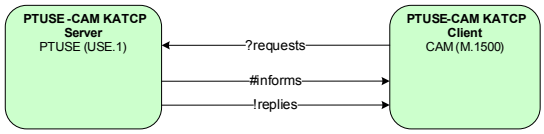

Figure 3: Flow of KATCP messages types

The following notes apply to the KATCP message descriptions in this section:

- The message grammar used is extended BNF and is fully described in [6]
- Data types of the message parameters are indicated as *(datatype)* next to the parameter descriptions. The KATCP data types are described in [6], section 3.

3.5.5.1.1. Standard KATCP Messages

Error! Reference source not found. provides the list of standard KATCP request messages that will be implemented. The requests that send inform messages as part of their reply are marked with *[informs]* in their description. More detail on these standard KATCP request messages can be found in [6]Error! Reference source not found.

The MeerKAT CAM (M1500) is responsible for implementing the KATCP client and PTUSE is responsible for implementing the KATCP server for this interface.

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Table 1: List of standard KATCP requests

Request name	Description	Requirement Number
?halt	Halt the PTUSE and put it into a state where it is safe to power down	IR.T.PTUSE-CAM.5
?restart	Re-initialise the PTUSE	IR.T.PTUSE-CAM.6
?help	Return help on the requests supported by a device [informs]	Derived
?log-level	Set or get the logging level	Derived
?client-list	List or identification of the PTUSE currently connected to CAM	IR.T.PTUSE-CAM.4
?version-list	Display revision and or build information[informs]	Derived
?sensor-list	List available sensors on a specific exposed component [informs]	Derived
?sensor-sampling	Configure a sampling strategy on the specified component sensor	Derived
?sensor-value	Retrieve a sensor value of a specific component sensor [informs]	IR.T.PTUSE-CAM.9 IR.T.PTUSE-CAM.10 IR.T.PTUSE-CAM.11
?watchdog	Check KATCP communications or ping CAM	Derived
?sensor-sampling-clear	Clear the sampling strategies of the specified component sensor(s)	Derived

3.5.5.1.2. KATCP Asynchronous informs

Error! Reference source not found. provides the list of standard KATCP asynchronous inform messages that will be implemented. More detail on these standard KATCP asynchronous inform messages can be found in [6].

Table 2: List of standard KACP asynchronous informs

Inform name	Description	Requirement Number
#disconnect	Provide the explanation for a server-initiated disconnection	Derived
#client-connected	Inform connected parties of a new connection	IR.T.PTUSE-CAM.4
#log	Generate human-readable log messages and errors	IR.T.PTUSE-CAM.8
#sensor-status	Report a sensor values	IR.T.PTUSE-CAM.10 IR.T.PTUSE-CAM.11
#version-connect	Display KATCP version, PTUSE software version and build information	Derived

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version-connect (Example)

INFORM `#version-connect`

Version inform message sent from the PTUSE (KATCP server) to any connecting KATCP client.

Format:

#version-connect katcp-protocol <katcp_protocol_version>

#version-connect katcp-library <katcp_library_version>

#version-connect katcp-device <device>-<version> <device>-<build_no>

Example:

#version-connect katcp-protocol 5.0-IM

#version-connect katcp-library katcp-python-0.5.5a0

#version-connect katcp-device acu-1.0 acu-0.4r1951

3.5.5.1.3. Application-specific KATCP Messages

Table 3 provides the list of application-specific KATCP request messages that will be implemented. The requests that send inform messages as part of their reply are marked with *[informs]* in their description. The table is followed by a more detailed description on each of these requests including any applicable inform and reply messages.

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Table 3: List of application specific KATCP requests

Request name	Description	Requirement Number
`?data-product-configure`	Prepare/configure the PTUSE for the reception of the product.	IR.T.PTUSE-CAM.7
`?capture-init`	Prepare the appropriate PTUSE ingest process for data capture.	Derived
`?capture-start`	Start to transmit SPEAD data to PTUSE	Derived
`?capture-stop`	Stop to transmit SPEAD data to PTUSE	Derived
`?capture-done`	PTUSE is informed that the current observation is done	Derived

REQUEST ***?capture-init*** *data_product_id*

Prepare PTUSE ingest process specified by *data_product_id* for data capture.

REPLY *!capture-init ok | (fail [error description])*

A successful return value indicates that PTUSE is ready for data capture and has sufficient resources available.

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An error will indicate that PTUSE is not in a position to accept data within constraints of the specified *data_product_id.*

REQUEST ***?data-product-configure*** *data_product_id antennas n_channels dump_rate n_beams_cbf_source*

Configure PTUSE for the particular data products

REPLY `!data-product-configure ok | (fail [error description])`

In order to allow PTUSE to make an estimate of its ability to process a particular data product, this command should be used to configure particular data products by specifying the antennas (used by owning sub-array of particular data product), number of channels, dump rate and number of beams that is expected to be produced by CBF. In case of a tied array product, the n_beams parameters should be set to a value greater than zero and will be used to determine the overall data rate and capture strategy.

The antennas should be a comma separated list of physical antenna names used in particular sub-array to which data products belongs.

In all cases a specification of the multicast address(es) to receive data from the CBF should be specified. The address numbering should be specified in a band order i.e. it is assumed that adjacent address contain adjacent segments of the RF band.

If a *data_product_id* is provided without arguments the configuration of the specified *data_product_id* will be returned. If no *data_product_id* is then given a list of all configured data products is returned.

If an existing *data_product_id* is used and the trailing argument exactly matches an already configured product, the command will return OK, but no action will be taken. If the arguments are mismatched the command will fail as the product must first be de-configured.

If antennas is set to an empty string, the specified *data_product_id* is deconfigured.

cbf_source has the format *<ip>[+<count>]:<port>,* represent SPEAD stream multicast groups. When a single logical stream requires too much bandwidth to accommodate as a single multicast group, the count parameter indicates the number of additional consecutively numbered multicast group *ip* addresses, and sharing the same UDP *port* number.

cbf_source is the data-product stream produced by CBF.

REQUEST ***?capture-start*** `data_product_id`

Request the PTUSE to start data capturing of the named `data_product_id`.

REPLY `!capture-start ok | (fail [error description])`

Reply to the capture-start request.

REQUEST `?`**`capture-stop`** `data_product_id`

Request the PTUSE to stop data capturing of the named `data_product_id`.

REPLY `!capture-stop ok | (fail [error description])`

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Reply to the capture-stop request.

REQUEST `?capture-done` *data_product_id*

Terminate the PTUSE ingest process for the particular *data_product_id*

REPLY `!capture-done ok | (fail [error description])`

This writes out any remaining metadata, closes all files, terminates any remaining processes and frees resources for the next data capture.

3.5.5.2. Primary PTUSE Sensors

The PTUSE provides the following sensor monitoring data to the CAM using KATCP sensors as specifed in [6]. The CAM will receive KATCP sensor inform from messages from PTUSE. Additional sensors not in this list may be available. These can be discovered using ?sensor-list. All sensors will conform to the status conventions, in particular failures and warnings will denote conditions warranting attention.

Refer to [6] for command and response format.

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Table 4: PTUSE KATCP Sensors

Name	Description	Value extent	Unit	KATCP Type	Req Number	Health Impact
device-status	Reports the health status of the PTUSE and associated devices: Among other things report HW failure, SW failure and observation failure *Note – additional device-status-xxx sensors can be made available for LRUs within the PTUSE as applicable.*	see Table 7	None	discrete	IR.T.PTUSE-CAM.9	N/A
pulsar-snr	Reports the sensor value of Signal-to-Noise Ratio of the PTUSE data	value	TBD	float	IR.T.PTUSE-CAM.10	nominal: ok warn/ error: degraded
beamformer-gain	Reports the Beamformer gain sensor value	TBD1 ≤ x ≤ TBD2: nominal (TBD3 < x ≤ TBD4): warn x < -TBD5 || x > TBD6: error	TBD	float	IR.T.PTUSE-CAM.11	nominal: ok warn/ error: degraded
local-time-synced	Indicates whether the local time of the PTUSE is synchronized to the master time reference.	0 = Not synchronized: error 1 = Synchronized: nominal	None	boolean	IR.T.PTUSE-CAM.4	

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3.5.5.3. Power Management

The interface between CAM and the PTUSE PDUs is via the Telescope LAN. Management of each PDU is performed directly by CAM.

To shut down PTUSE, a `halt` request must be issued on PTUSE servers and they must be allowed at least 60 seconds to shut down the software. Once this `halt` command completes, the power down is issued directly to PTUSE PDUs based on a naming convention of PTUSE PDUs.

3.5.6. Metadata Application Layer

CAM provides a WebSocket server to deliver metadata to PTUSE. The address will be configured on the KATCP interface. The PTUSE interface to CAM is implemented as a python client and sends JSONRPC messages to CAM to subscribe and unsubscribe to sensors and to set its sampling strategy. Depending on the sampling strategy, CAM responds to the PTUSE interface with asynchronous messages containing sensor data. The WebSocket methods are described in the paragraphs below.

3.5.6.1. Message Types

CAM provices a client called katportalclient that abstracts the underlying complexity of WebSockets and JSON-RPC messages away. The client exposes the following methods:

- subscribe
- unsubscribe
- set_sampling_strateg(y/ies)

The katportal server responds asynchronously with a result with the request id.

Table 5 shows the Pub/Sub requests that the katportalclient exposes.

Table 5: Pub/Sub Request

Request	Description
`subscribe`	Subscribes to a sensor name of which sensor values are needed from CAM
`unsubscribe`	Unsubscribe will notify CAM to stop sending sensor values to the PTUSE interface
`set_sampling_strateg(y/ies)`	Update the sensor sampling strategy

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3.5.6.2. **Message Format**

Messages are sent using the katportalclient provided by CAM.

Each request is met with a reply of the following format:

- result (Object, Array, or Value): The result of the request. Must not exist if there was an error
- error (Error Object): A description of the error. Must not exist if no error occurred.
- Id (Value): Must be the same as the identifier used in the request.

The Error object must contain an integer error code ("code") and a descriptive error string ("message"). An optional "data" object may provide more detailed information.

For example:

```
{
   “id”: 66d284fe8e,
   “result”:
   {
      “msg”: “Hello JSON-RPC”,
      “timestamp”: “2015-04-14T12:00:00Z“
   }
}
OR
{
   “id”: 1,
   “error”:
   {
      “code”: 32001,
      “message”: “Unable to echo at this time!”
   }
}
```

Asynchronous sensor value updates follow the same format as a reply, but the “id” field is a fixed string identifying the update notification.

For example:

```
{
   “id”: “redis-pubsub-init”,
   “result”:
   [{
      “msg_channel”: “mon:sys_interlock_state”,
      “msg_data”:
      {
         “name”: “sys_interlock_state”,
```

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```
        "timestamp": "1431952166.486",
        "timestamp": "1435552166.486",
        "status": "nominal",
        "value": "NONE"
      }
   }]
}
```

3.5.6.3. **Subscribe Request**

Subscribing is done on a namespace basis, which is then reused when setting the sensor's sampling strategy. Subscribing to a namespace, for example "ptuse" will return all sensor values that were set to publish to that namespace.

Directly after the subscription an initial sensor update will be received with the current value of the subscribed sensor(s). The "id" of this update message will always be "redis-pubsub-init". Future updates of sensors will have an "id" of "redis-pubsub".

3.5.6.4. **Unsubscribe Request**

Unsubscribing is called in the same way subscribe is used. Supplying a namespace to unsubscribe will inform CAM to stop sending sensor values.

3.5.6.5. **Setting sampling strategies**

Setting sampling strategies takes three parameters. A namespace, a regular expression (or array of regular expressions) of sensor names and a sampling strategy. I.e. 'ptuse, ['mode', 'azim', 'elev'], 'period 1.0'

Different sensor sampling strategies as defined by CAM:

Description: The sensor sampling strategy used by the CAM. This determines under which conditions the CAM Subsystem will send sensor updates to the user. There are 7 strategies:

1. auto
2. none
3. period
4. event
5. differential
6. event-rate
7. differential-rate

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An “event” strategy set on a sensor will cause a sensor update every time that the sensor value or status changes.

A “period” strategy set on a sensor will cause an update to be sent at regular time intervals.

Representation: “<strategy> <strategy parameter>”

Where:

- <strategy> is {“event”, “period”}
- <strategy parameter> is applicable to “period” only, and is the period in seconds.

For example:

“strategy=period 60” for a 60 second update rate.

“strategy=event” for an event update rate.

3.5.7. Example of KATCP protocol exchange

Examples and descriptions of the messages that can be implemented by the system are given in Table 6 below.

Table 6: Examples of KATCP commands

KATCP messages	Description
?data-product-configure TBD M001,m002,m003,m004,m005 4096 1.0 TBD *!data-product-configure ok*	Request PTUSE to configure particular data products by specifying the antennas, number of channels, dump rate and number of beams that is expected to be produced by CBF
?capture-init TBD *!capture-init ok*	Request PTUSE to prepare ingest process for specified data product for data capture.
?capture-start TBD *!capture-start ok*	Request the PTUSE to start capturing SPEAD data from CBF subsystem
?sensor-value device-status #sensor-value 1362383432.104 1 device-status nominal 1 *!sensor-value ok 1*	Query the health condition of the PTUSE device status by requesting the value of the provided KATCP sensor. The sensor value returns through an inform message which indicates that the PTUSE device is ok.
?sensor-list beamformer-gain #sensor-list beamformer-gain beamformer_gain_value none float TBD1 TBD2 TBD3 TBD4 *!sensor-list ok 1*	List a specific sensor. Return values: name, description, measurement unit, datatype, nominal-min, nominal-max, warn-min, warn-max.

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KATCP messages	Description
?capture-stop TBD !capture-stop ok	Request the PTUSE to stop data capturing of the named data_product_id
?capture-done TBD !capture-done ok	Terminate the PTUSE ingest process for the particular data_product_id

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3.5.7.1. Health KATCP Sensor

The PTUSE will provide a health KATCP sensor, as defined in [6] appendix B par. B.2, identified as `device-status` with type and values *(discrete, ok | degraded | fail)*.

Table 7: Health sensor conditions

Value	Status	Description	Conditions
ok	warn	PTUSE is fully operational	See "Health Impact" column in Error! Reference source not found.
degraded	warn	PTUSE is capable of operation with reduced performance and reliability	See "Health Impact" column in Error! Reference source not found.
fail	error	PTUSE is unusable	See "Health Impact" column in Error! Reference source not found.

Note that the most severe health status always overrides a less severe health status, e.g. even though there might be multiple 'degraded' conditions present and only one 'fail' condition the health status should report 'fail' in such a case.

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