Advanced Multi-Beam Spectrometer for the GBT

Conceptual Software Design

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NRAO and U.C. Berkeley Joint
Conceptual Design Review
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Conceptual Software Design

- M&C
  - Clock synthesizer
  - Per spectrometer
    - HPC
    - Roach board
  - Integration into GBT system – antenna movement, configuration, IF balancing, etc
- User Interfaces
  - Observing
  - Engineering
- Data Analysis
  - Real-time display
  - Pipeline
- .Does NOT include design for archive or address future VO-compatibility

The GBT M&C System

- Distributed, object-oriented telescope control system written in C++
- Radio telescope is defined as a laboratory rather than an instrument
  - Each device (e.g. receiver, backend) is an autonomous subsystem
  - Participates in an observation in coordination with other devices
- Each device requires no more than four interfaces
  - Control, Monitor, Message/Alarm, and Data
- The interfaces for each device are provided via a *Manager*
  - Control → *Parameter*
  - Monitor → *Sampler*
  - Messages/Alarms → *Message*
  - Data → *FitsIO*

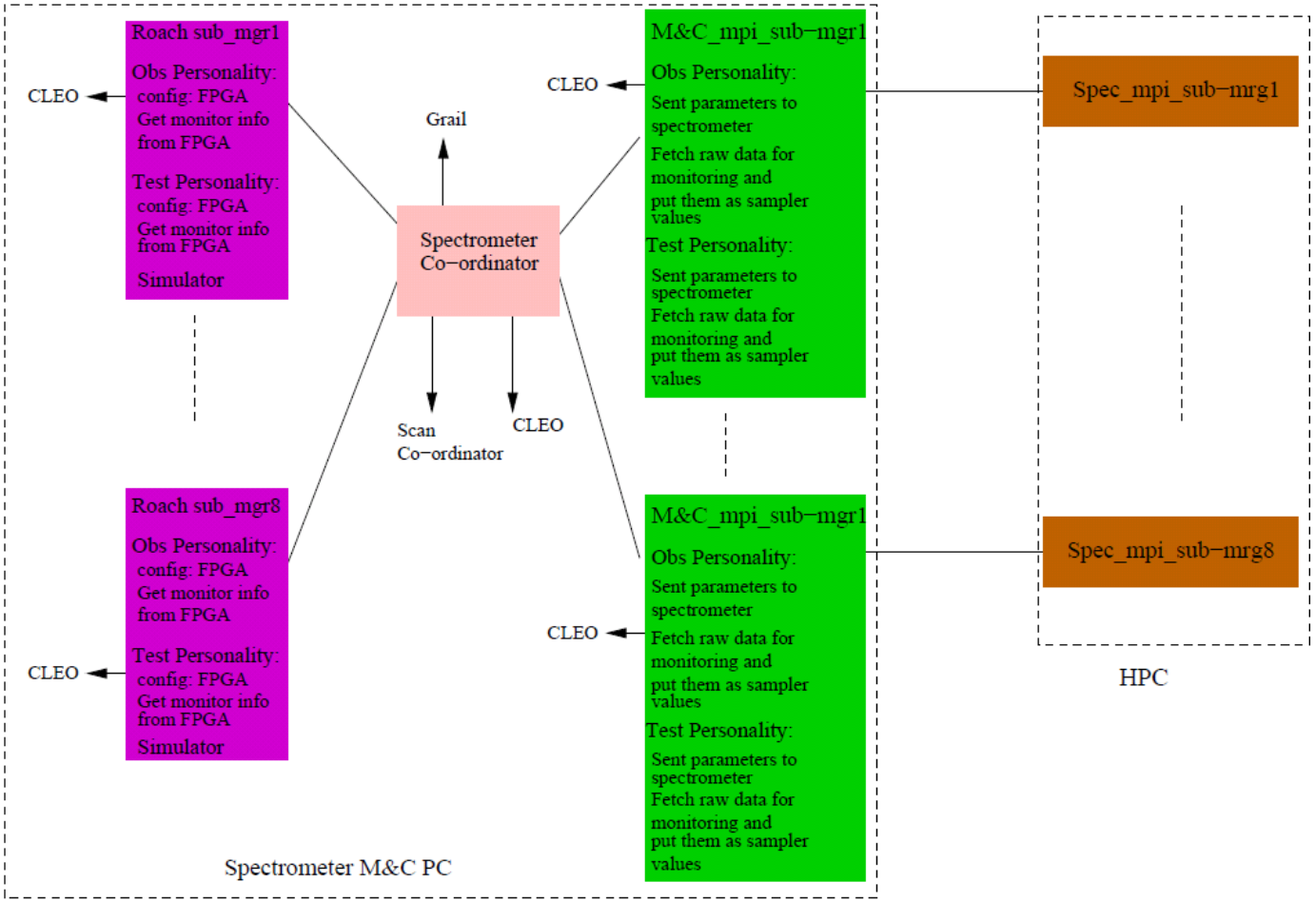
Spectrometer Monitor & Control

- Create a M&C *Coordinator* with 8 sub-*Managers*, one per spectrometer
  - The *Coordinator* provides a uniform interface to the spectrometers and provides M&C for the clock synthesizer.
- Implement all of the four possible interfaces in the *Manager*
  - Control, Monitor, Message/Alarm, Data
- M&C details for HPCs & Roach boards are TBD
  - Waiting on approved hardware design
- M&C for the clock synthesizer is being designed
- **Important design consideration** – The software infrastructure must reflect the modularity of the hardware and expand easily to accommodate future growth.

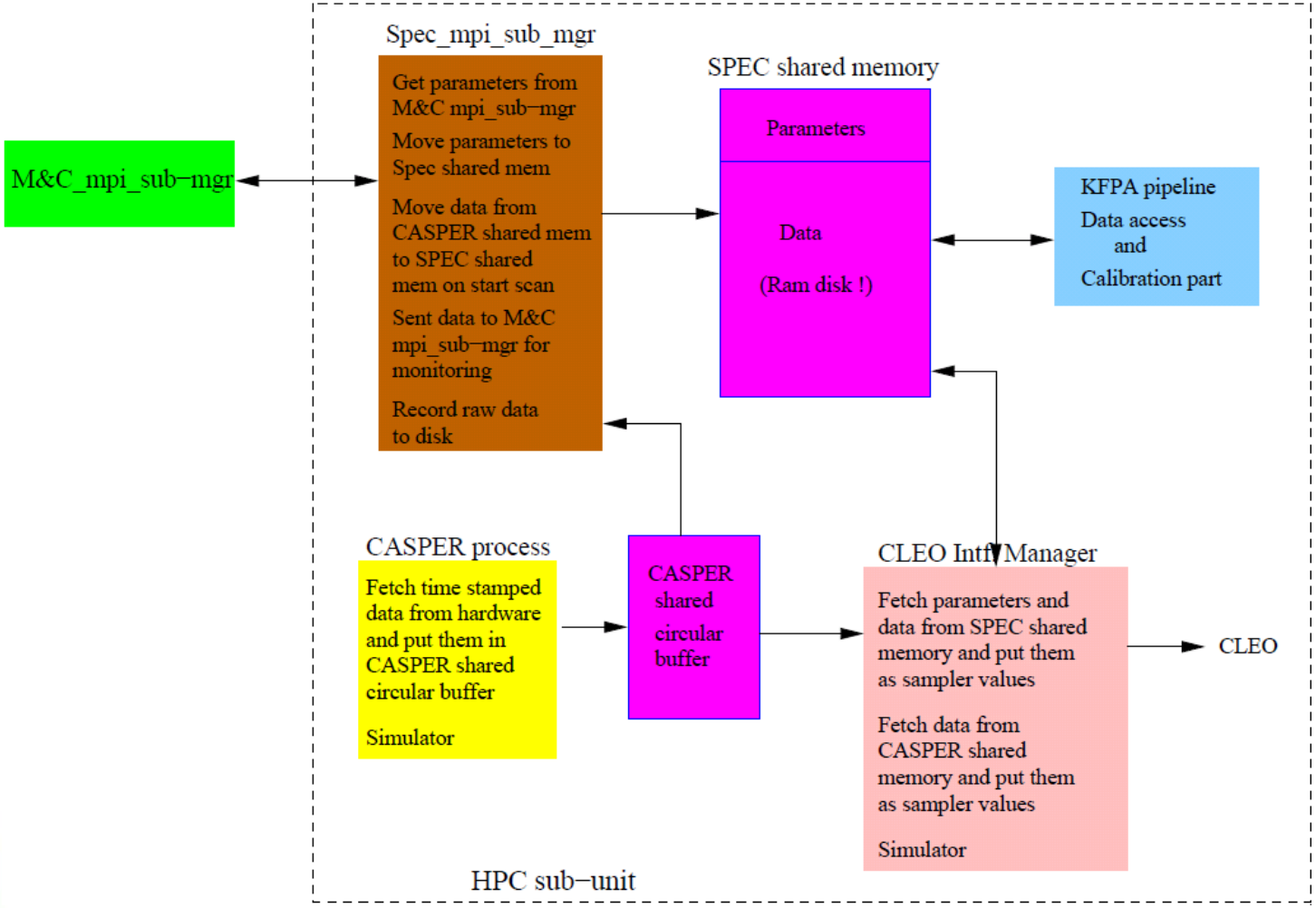
Spectrometer Monitor & Control (2)

- Plan to replace files as an inter-process communication mechanism between data acquisition and data analysis software
  - Current system exclusively using files.
  - Causes frequency problems with remotely mounted directories. We're abusing NFS.
  - BIG JOB!
- Will continue to write FITS files for offline data processing
  - We need to do this for those interested in using GBTIDL
  - We need to do this for those who have tools that assume FITS file available
- PSR FITS when appropriate
- Probably also writing HDF5 files
  - FITS is not a good choice for large data sets
  - HDF5 is an emerging standard for large data sets
  - Opens the door to leveraging 3rd party data analysis applications that read HDF5

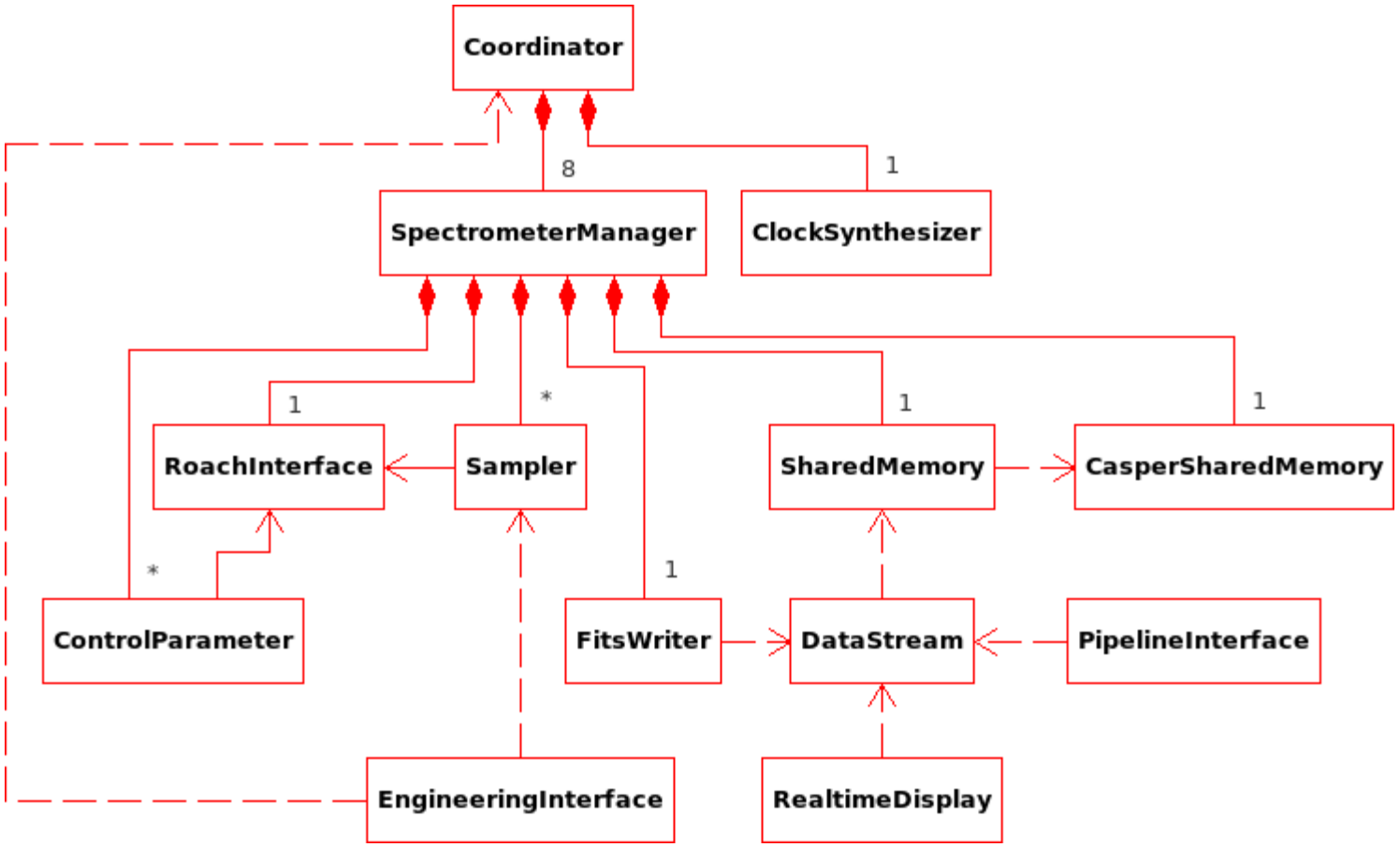
Conceptual Block Diagram



Sub-Manager Conceptual Block Diagram



Object Diagram



Monitoring

- Individual monitor values are grouped into a *Sampler*, which contains the monitored values along with a *TimeStamp*
- *Samplers* can be recorded to FITS files ad hoc via sampler2log
- Need to monitor Roach boards, clock synthesizer, and data (at slower rate than acquisition)

Control

- Individual control values are represented via a *Parameter*
- Need to control
  - Roach boards
  - Clock synthesizer
  - HPCs

Messages (Alarms)

- *Messages* are assigned a severity level
  - Information, Notice, Warning, Error, Fault, or Fatal
- Managers come with a number of predefined *Messages*
- Custom *Messages* for the Spectrometer will be implemented according to specifications provided by the hardware engineers and GBT operations.

Data

- Written to shared memory & made available via a data stream
  - A data stream is a process that accepts multiple connections and provides Spectrometer data in real-time through those connections.
- Processes attaching to the data stream from the Spectrometer
  - Data recording (FITS, HDF5?)
  - Pipeline
  - Real-time data display (GFM)
  - Anything else that might be interested in the data
- Planning to save raw data for offline processing or reprocessing
- Will synchronize data time stamps across all spectrometers & data recording on scan start via NTP.
- Will be able to import into GBTIDL as with current ACS. Especially important for non-mapping, low data rate observations.

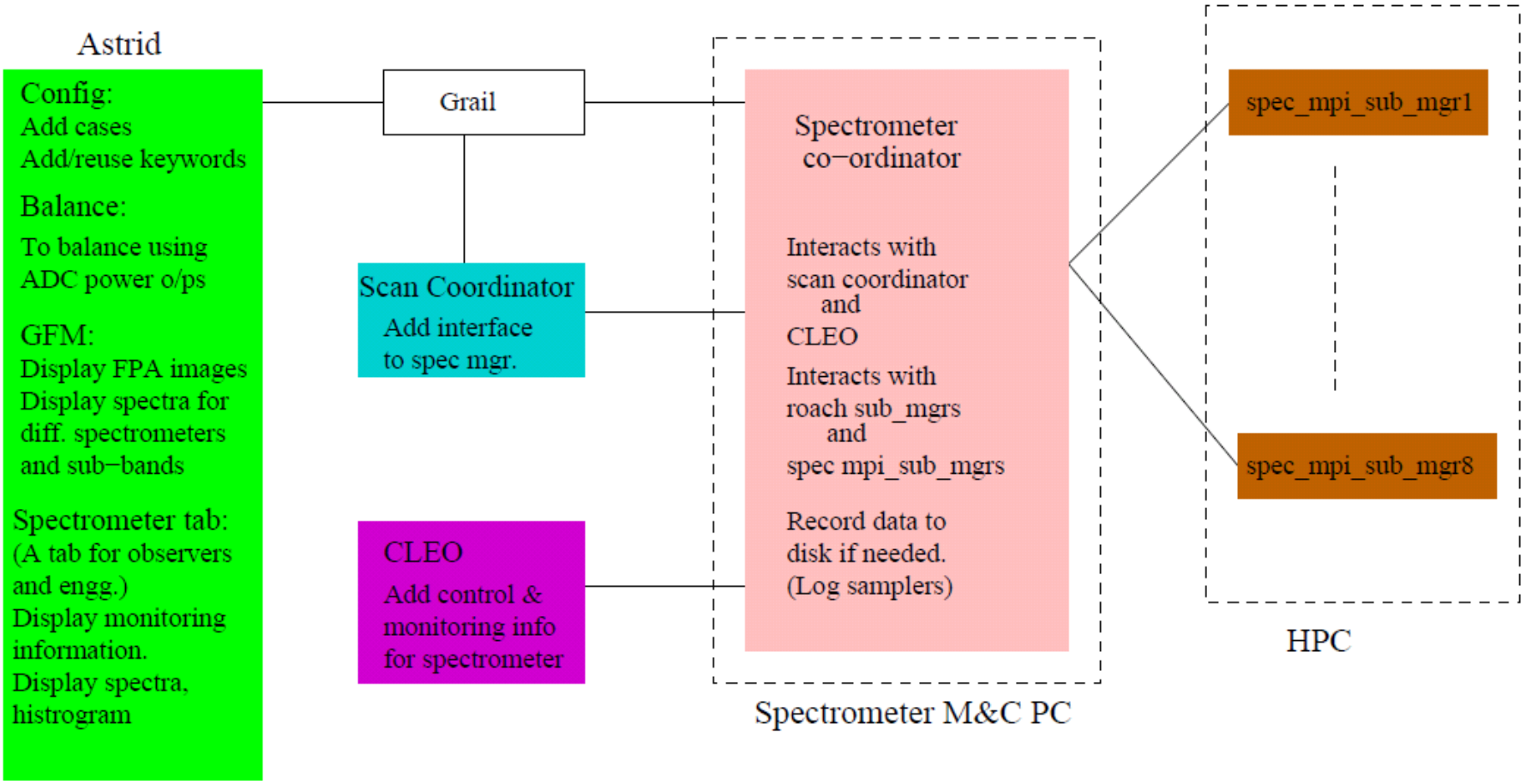
Roadmap to GBT M&C Integration

- The creation of the *Coordinator* and *Managers* is the first step and handles the hardware M&C functionality and data acquisition
- Introduction of the Spectrometer *Manager* into the M&C system is trivially accomplished via configuration files
- Additional work is required for full integration as a common user instrument…

Roadmap to GBT M&C Integration (2)

- Modification of the *IF Manager* to properly simulate the IF path to backend
- Modification of the *Configuration API*
- Modification of the *Balance API*
- Possible changes to the *Observation API* used by observers when writing Scheduling Blocks for observing
- Integration into data quick look (GFM) spectral line plugin
- Possibly a custom Spectrometer tab in Observer's GUI (Astrid)
- Engineers and Operator's Interface
  - Integration into the Engineers & Operator's GUI (CLEO)
  - Detailed version of Astrid tab for use by engineers
- Data pipeline (more on that in a bit)

Conceptual Block Diagram



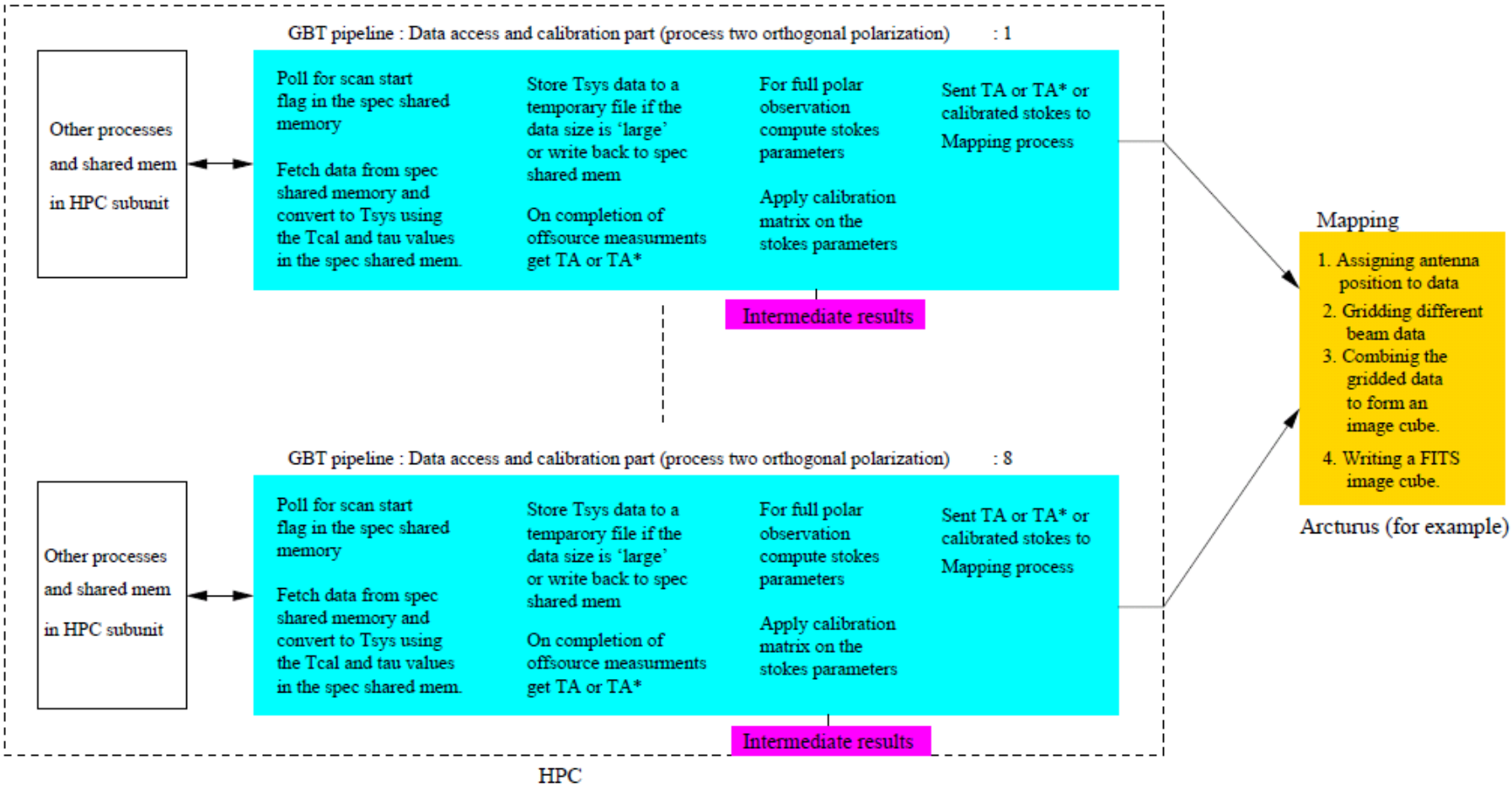
The Current KFPA Pipeline

- Handles position switched observations
- Will handle frequency switched observations
- Already written for parallel processing (some)
- Written as generically as possible – not just KFPA observations
- No real-time data processing. Everything done after all data recorded.

Pipeline for the Spectrometer

- The ultimate goals of the Spectrometer pipeline are:
  - To use exclusively data streams and/or samplers for online data processing for Spectrometer observations.
  - To satisfy the data calibration and mapping requirements and observing modes for Spectrometer observations.
- Some existing software infrastructure will be reused
- Need to replace significant parts of the infrastructure to support faster data rates and larger data sets. Also need to enhance reliability. For example:
  - Current software for creating SDFITS files falls behind for high data rate observations with current Spectrometer.
  - System state changes sometimes missed by online sdfits
- Need to take advantage of the data stream from the Spectrometer
- Need to ensure calibration pipeline scalable for more spectrometers
- Mapping step of pipeline requires faster antenna position sampling
- Plus laundry list of future features TBD
  - Includes support for polarization observations

Conceptual Block Diagram



Phased Development Plan

- Ideally, all observation data should be available in streams. However, that involves **a lot** of retrofitting.
- With a phased plan, we mitigate risks associated with limited software resources.
- Each phase of the staged implementation delivers a working pipeline that leverages as much existing infrastructure as possible while incrementally introducing new development and infrastructure necessary to achieve our final implementation goal.
- Three phases:
  - Retool GBT pipeline to reduce Spectrometer data. Attach to existing Samplers with information of interest for calibration.
  - Retrofit Managers producing "static" scan information to use streams
    - E.g. IF Manager, LO1 Manager, Measurements Manager
  - Retrofit the Antenna Manager to stream position data

Important Pipeline Considerations

- We need a plan and corresponding policy for data reduction post observation. If we expect observers to rerun the pipeline post-observation, we need to provide access to machines to do such reduction along with an enforced policy for access to those machines.
- Still need a plan for data archiving
  - Do we want to consider the VAO and VAO-compatibility as part of our archiving plan?
- Need to identify data analysis and reduction tools from other observatories and/or fields of interest and consider support for their data product formats.
  - Leverage tools rather than reinventing them

Test Bed for Software Development