The APEX Control System*
Past, Present & Future


* APECS
APECS’ Roots in ALMA

- Early (1999/2000) contact to ALMA software development groups since APEX will be a copy of an ALMA prototype antenna
- Worked in SSR & HLA groups
- Later followed Test Interferometer Control Software (TICS) developments
- Evaluated ALMA-TI FITS raw data format for use at APEX
- Now still working for ALMA (DC, Heuristics)
Lessons learned from ALMA Work

- **Interfaces must be stable early on**
- **Object-oriented software analysis & design**
- **Unified Modeling Language (UML)** (A standardized way of translating requirements into a class and object structure)
- **Distributed computing using a middleware like CORBA** (Common Object Request Broker Architecture)
Don’t panic! I’m just an object.

Name: FLASH810
Properties: Frequency, Sideband
Methods: On, Tune, Off
Inherited ALMA Software

APECS re-uses a large portion of the original ALMA Test Facility (ATF) software

Advantages:
- Common hardware & interfaces
- Real-time software already developed
- Big development team (->2003: 15, 2003->: 50)
- Potential upgrades (and support) in the future

Disadvantages:
- APEX is an early adopter. Steep learning curve.
- Initial releases are typically unstable
ALMA Common Software

ACS (v1.1 & v2.0.1) provides:
● CORBA
● Distributed Objects (Container / Component model) to abstract hardware
● Configuration database
● Property value monitoring
● Multi-language environment (C++, Python, Java)
CORBA facilitates the communication among pieces of software in distributed, heterogeneous, multilanguage environments.

CORBA

Client

Object Implementation

Request

ORB
Test Interferometer Control Software

TICS (v0.2, v0.5 & April 2004) provides:

- Real-time software (VxWorks)
- CAN (Controller Area Network) CORBA objects and bus interface to VERTEX ACU/PTC
- Astronomical coordinate handling (descriptive RA/Dec and horizontal)
- Basic patterns (linear, arc, curve strokes including On-The-Fly mode)
- Monitoring database
- Optical pointing
APECS Developments

ACS & TICS provide the basic infrastructure but a full telescope control system requires:

- Hardware interfaces ("IDL", "SCPI")
- Raw data format ("MBFITS")
- High-level observer interface ("apecs CLI")
- Observation coordination ("Observing Engine")
- Raw data writing ("FitsWriter")
- Online calibration pipeline ("Calibrator")
- Automatic observation logging ("Observation Logger")
- Monitoring tools ("Monitoring Engine")
Hardware Interfaces

- For each device one needs a CORBA Interface Definition Language (IDL) file
- CORBA C++ code is complicated. Instead embedded APEX systems use a simple ASCII protocol based on SCPI* commands sent via UDP sockets
- SCPI commands are derived from naming hierarchy and method and property names
- C++ code is auto-generated from IDLs

*Standard Commands for Programmable Instrumentation
SCPI Syntax Example

Component sends the device:

[APEX:]<device name>[:<property name>]?

The device replies:

[APEX:]<device name>[:<property name>] <value> \ 
<ISO 8601 time stamp>

Example:

APEX:HET460:LO2:MULTI1:backShort2?

APEX:HET460:LO2:MULTI1:backShort2 2.341 \ 
2003-11-05T10:19:38.310+00.00
APECS uses high-level interfaces that are designed to be generic, i.e. applicable to any instrument of a given class (e.g. heterodyne receivers or continuum backends).

The instrument setup thus needs to be implemented only once.

Adding new instruments to the system is reduced to simply adding names.
Multi-Beam FITS (MBFITS)

- ALMA-TI FITS turned out to be unsuitable for the multi-beam single-dish data expected for APEX
- Began extending ALMA-TI FITS together with IRAM 30m and Effelsberg with the goal to share (mainly calibration) software
- Many detailed iteration cycles led to the MBFITS format which is now well iterated, stable and has been in use for 2 years
MBFITS block diagram v.1.2

**Primary Header**

**Observing setup**
- SCAN
- FEBE 1 header
- FEBE 2 header
- Table

**Header**
- ARRAYDATA
- MONITOR
- DATAPAR

**Observation**
1. 3 basebands FEBE 1
2. 2 basebands FEBE 2

**Raw backend data**

**Raw monitor data**

**Data associated parameters**

**Integrations**
(for each observation)
- ARRAYDATA table
- MONITOR table
- DATAPAR table

3 basebands FEBE 1
2 basebands FEBE 2
“apecs” Command Line Interface

- IPython based CLI with extensible scripting language including user macros
- High-level commands to set up:
  - Catalogs (source, line)
  - Targets (coordinates, velocity)
  - Instruments (frontends, backends)
  - Calibrations (sky-hot-cold, skydip, point, focus)
  - Switch modes (total power, wobbling, freq. sw.)
  - Patterns (single, raster, OTF, (spiral))
<heterodyne frontend name>.derotate, <frontend name>.backends,
<continuum / spectral backend name>,
<spectral backend name>_group

Target: source
Calibration: calibrate, skydip, point, pcorr, pcorr_reset, focus, fcorr,
             fcorr_reset
Pattern: offset, reference, use_ref, on, raster, otf, spiral, repeat
Switch mode: tp, wob, fsw
Antenna: tolerance, park, stow, unstow

APECS> frontends 'flash810'
------> frontends('flash810')
Modifying original frontend delta pointing model by (0.0", 0.0")
to recenter to feed number 1.

APECS> flash810.backends 'ffts'
------> flash810.backends('ffts')
Setting dump time of 1.000000 seconds for backend FFTS.
Connecting section group 1 of backend FFTS to frontend FLASH810.
Configuring section group 1 of backend FFTS.
Resetting number of repeats to 1.

APECS> source 'jupiter'
------> source('jupiter')
Setting up solar system body Jupiter.
Currently at Az=73.0° / El=70.6°. Distance to the Sun: 118.7°.
Resetting source offsets to (0.0, 0.0, system='EQ').
Resetting number of repeats to 1.
Observing Engine

- Central coordinating process that sets up all devices according to the “Scan Objects” sent via the “apecs” CLI
- Pattern loop to set up receivers, IF, backends, antenna motion and start / stop FitsWriter and backends
- Background threads to update weather and IERS parameters needed for coordinate and refraction calculations
Observing Engine Interactions
FitsWriter

- The FitsWriter creates MBFITS files by collecting telescope, backend and monitoring data via a set of pipelines.
- Each pipeline consists of pipes and filters and feeds a particular type of MBFITS binary table.
- A flexible mechanism allows to store any CORBA property at any given rate in the MONITOR table.
The calibrator provides the online pipeline to process the MBFITS files after each sub-scan.

Spectral line data is calibrated to $T_A^*$ scale using ATM and written to CLASS format.

Bolometer data is processed using the BoA modules.

Pointing & focus results are made available to the “a pecs” C LI for corrections.
Observation Logger

- Automatic creation of the observer’s log (XML & HTML) using the online information
- Allows editing a comment field for each scan
- Visible columns can be selected individually
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<th>CA</th>
<th>IE</th>
<th>Type</th>
<th>PWV</th>
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Scan canceled.
Monitoring Engine

- Generic graphical status display engine using the ACS archiving notification channel.
- Displays can be created using the standard "Qt Designer" program obeying a given naming convention for values, descriptions and units.
APECS Key Facts

- Modern object-oriented & distributed design
- Generic instrument interfaces facilitate adding new devices
- Automatic interface code generator
- Simple ASCII communication to embedded systems
- High-level scripting language
- Generic GUIs
- Monitoring database
- Simulation system for developments (demo)
Future APECS Developments I

- New observing patterns (spirals, circles, more complex lists of strokes)
- Array de-rotation
- Frequency switching mode
- Wobbler mode
Future APECS Developments II

- MBFITS split into several files using FITS hierarchical groups
- Porting to ACS 5 under Scientific Linux 4.2
- New servers for Chajnantor
- “xapecs” GUI