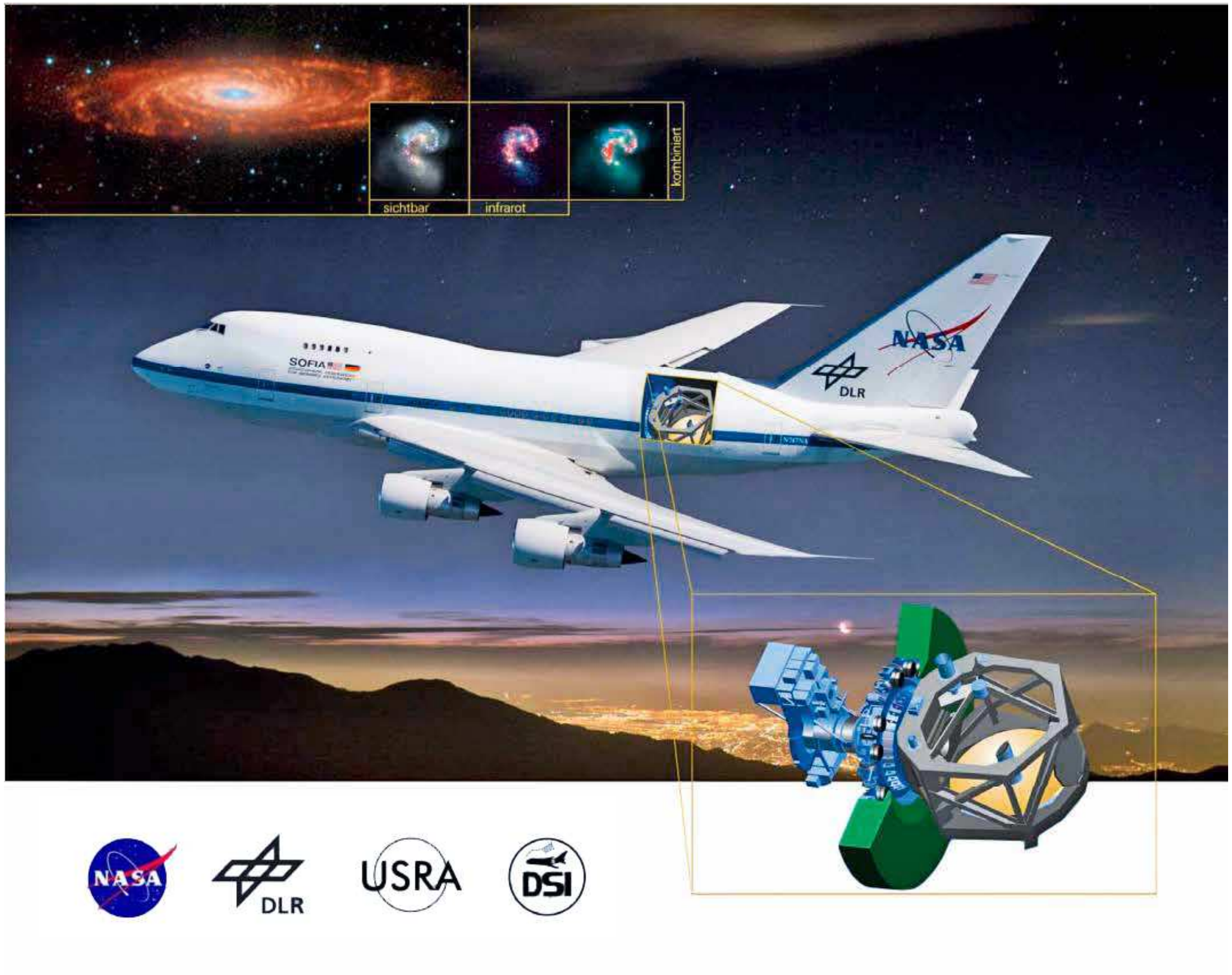
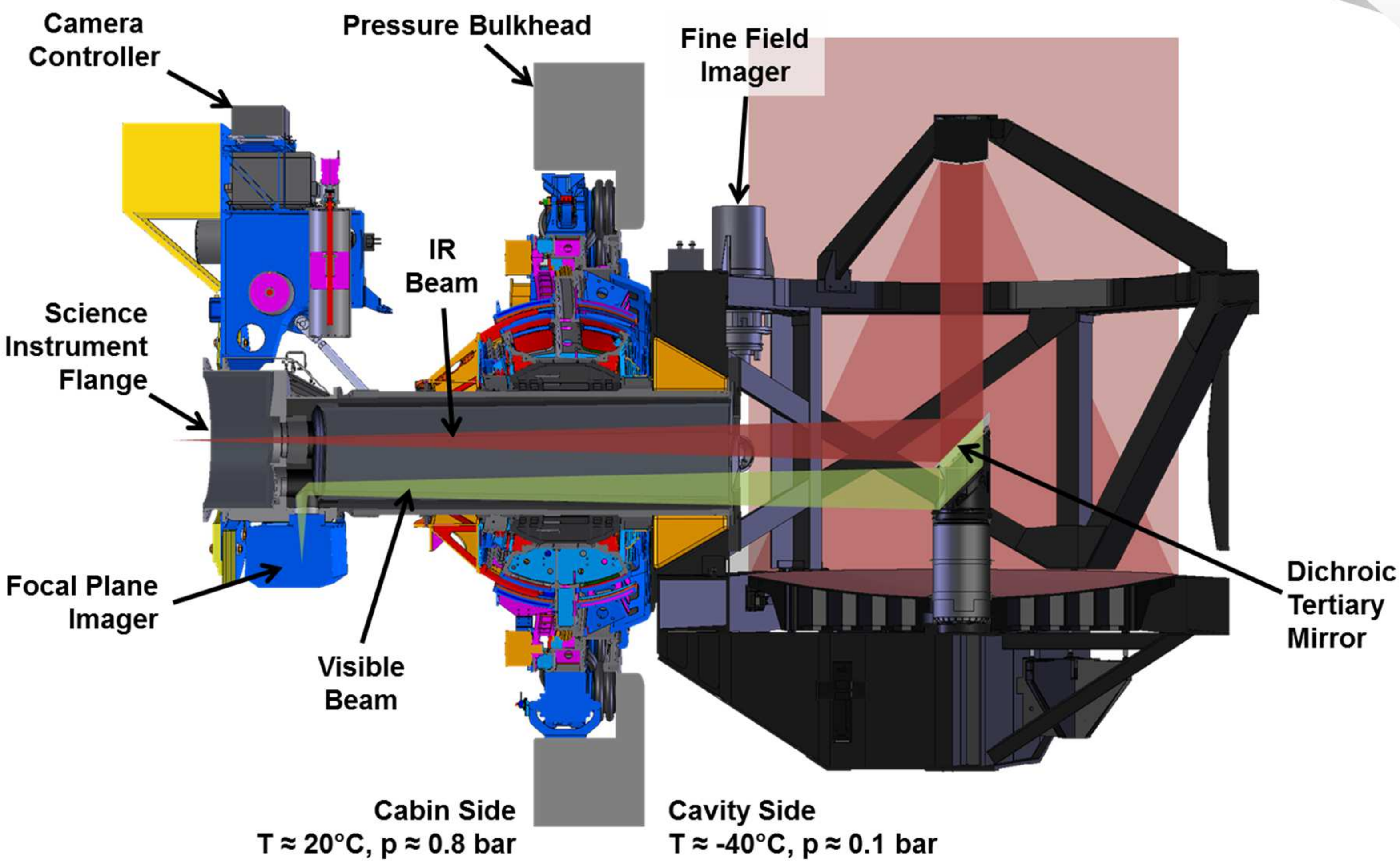
EVOLUTION OF THE SOFIA TRACKING SYSTEM

SPIE Astronomical Telescopes & Instrumentation 2014
Norbert Fiebig, J. Wolf, M. Wiedemann, E.Pfüller, H.Jakob, H.P. Röser

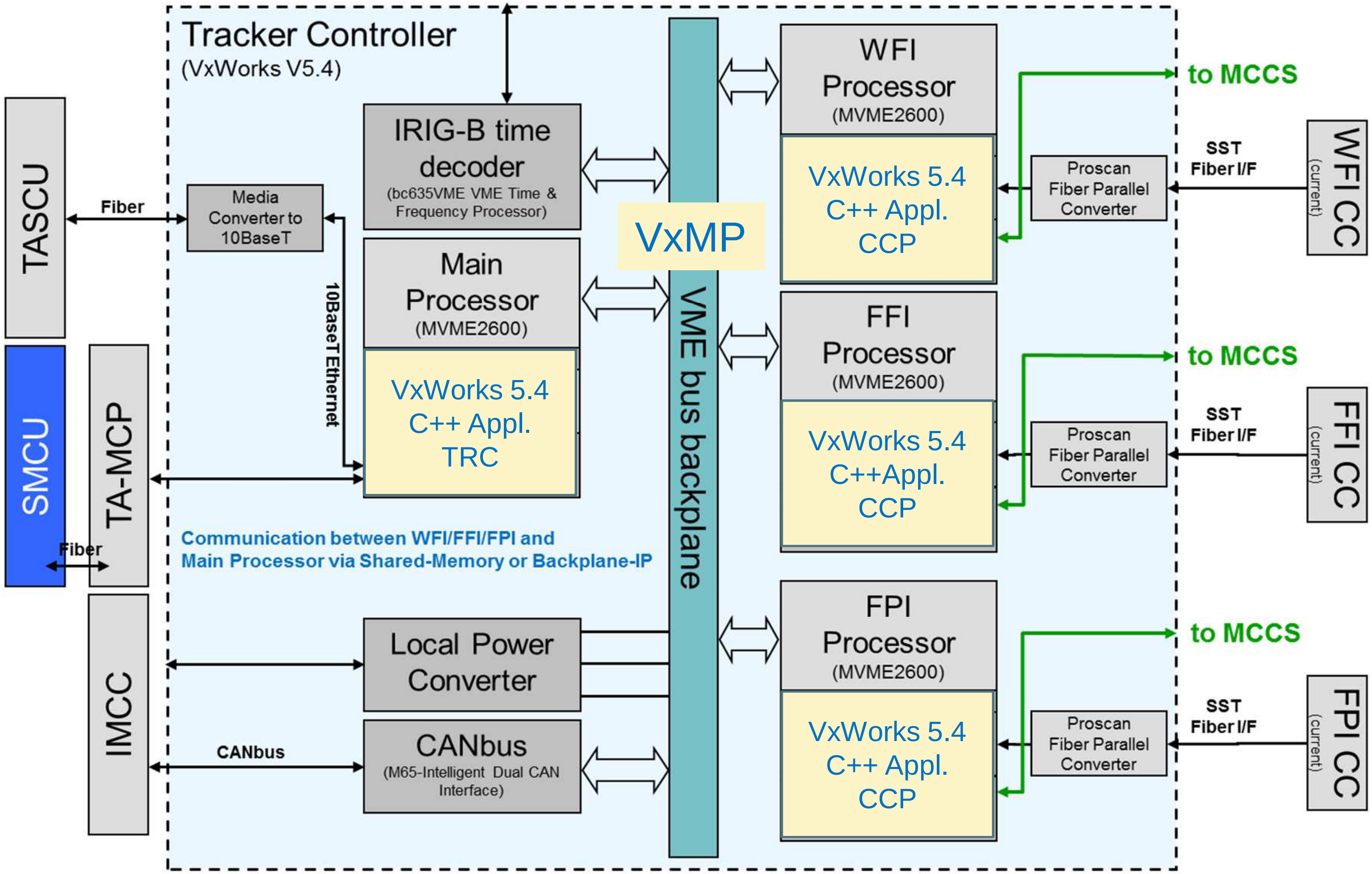
The SOFIA Observatory



The SOFIA Telescope



SOFIA Tracker Controller Architecture



Tracking System Upgrade

- Upgrade of the cameras by high-sensitivity Andor iXon3 DU-888 cameras with EMCCD sensors; new filter wheels
- Replacement of the camera control computers by embedded industrial PCs, which also replace the camera control electronics boxes and accommodate the camera interface cards
- Replacement of the remaining VME CPU boards by modern RIO 4 boards
- Migration from VxWorks to Linux and development of a new software application for the new camera controllers
- Redesign of the Tracker software architecture
- Upgrade to Gbit LAN

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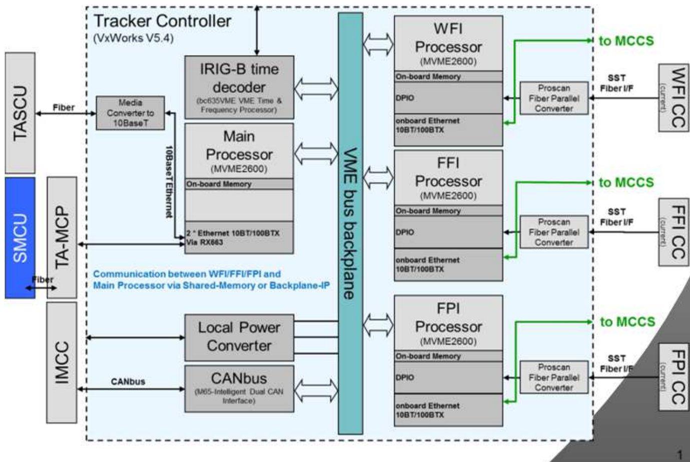
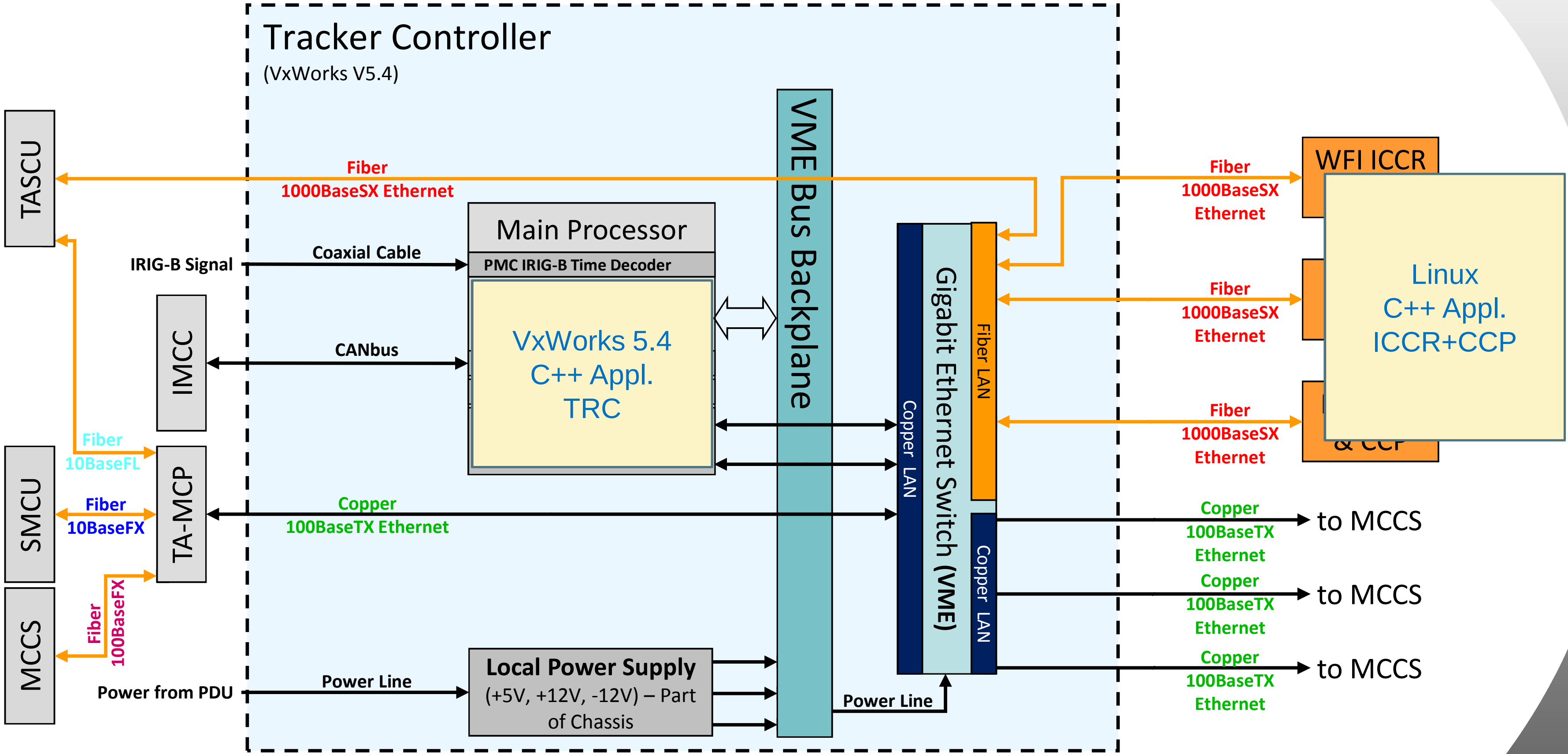


Redesigned Tracker Architecture

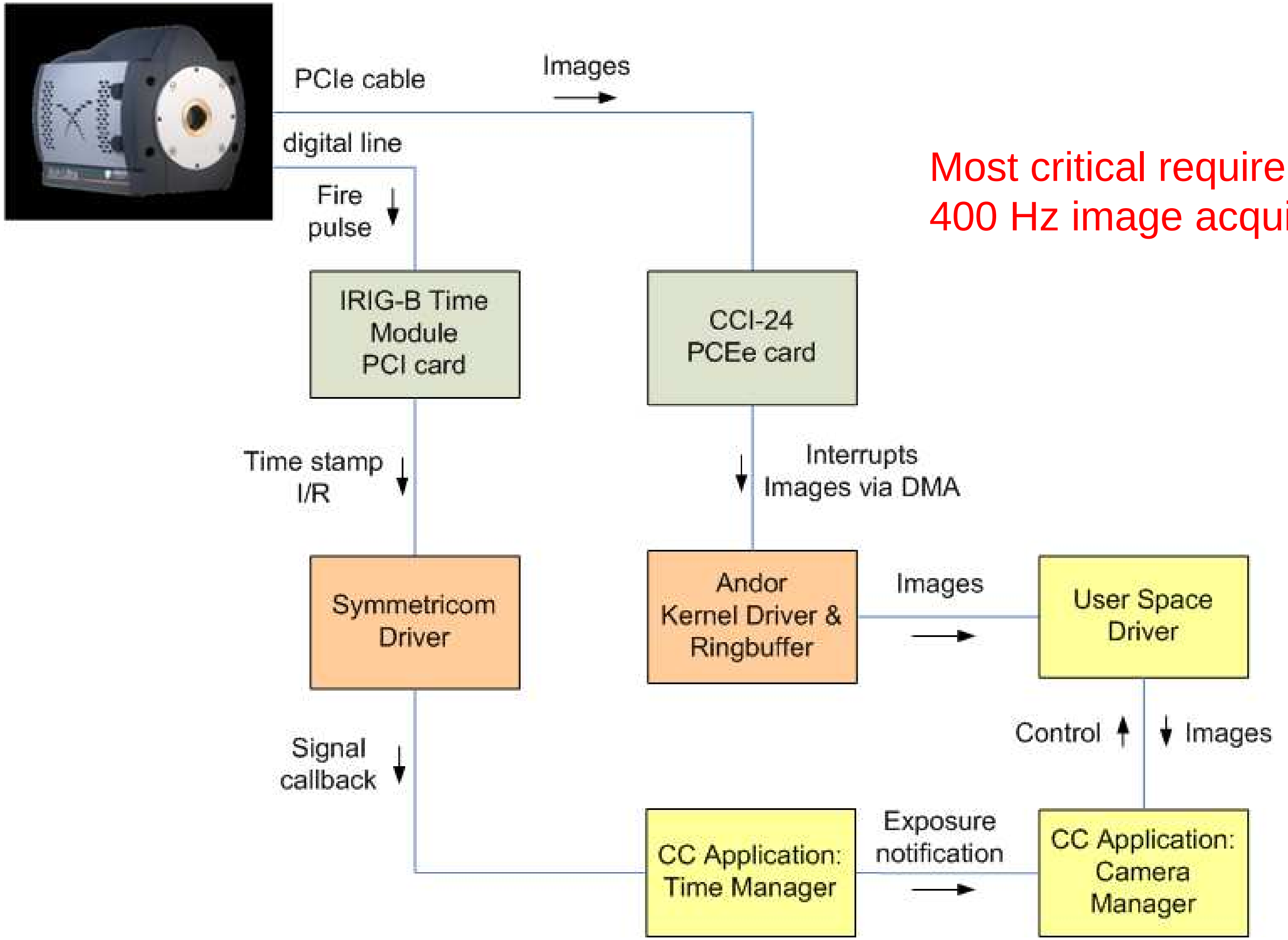


Norbert Fiebig
redlogix GmbH

VxWorks vs. Linux

- VxWorks 5.4 not available for new hardware out of the box
- BSP could be ported, but no use of multi core, cache system, SSE instructions, etc.
- VxWorks 6.x supports new hardware and modern features; however economically difficult
- Software redesign necessary anyhow
- Analysis showed that computing power is needed, but real-time demands are modest
- Decision for migration to Linux for the CCs – if R/T demands are matched

Camera controller RT demands



Most critical requirement:
400 Hz image acquisition rate

CC Linux kernel – problems and lessons

- Requirement for long term availability, flight-secure, controlled updates, etc.
- Find a kernel / distribution that supports all our drivers (Ubuntu 10.04.2 LTS) => decouple kernel from app. dev.
- Some effort to configure the Kernel for small memory footprint, fast boot, no swap, etc. => customized kernel
- ACPI caused camera driver to hang
- Tricky DMA configuration to optimize image rate
- Ext4 file system showed a performance issue with many small files
- No real taskLock/intLock on application level
- Conclusion: Linux suitable, but needs much know how and effort to establish and maintain; results in your own distribution

RTOS: Linux vs. VxWorks

Topic	VxWorks	Linux
Availability	5.x on new HW -> no go migration to 6.x: cost, effort	available out of the box
Configuration	small footprint, short boot time, easy configuration out of the box	can be achieved with more effort
Performance	very good, but not really comparable	factor of > 50 wrt. numeric, I/O (DMA, network) and disk performance compared to old system
Scheduling	preemptive, priority-based, deterministic taskLock/intLock, auto-unlock; WD timer	weaker, RT_PREMPT patch helps, Xenomai for hard R/T
Drivers	Less available, no Andor	Take care about kernel version
SW Architecture	Thread system, for small to medium applications	Process / thread system, suitable also for large and complex applications
Ecosystem		much richer, better networking

CC layered architecture

Communication protocol SOFIA (INDI, openTPL, EPICS)

Application layer

Infrastructure Software | Driver sub-system

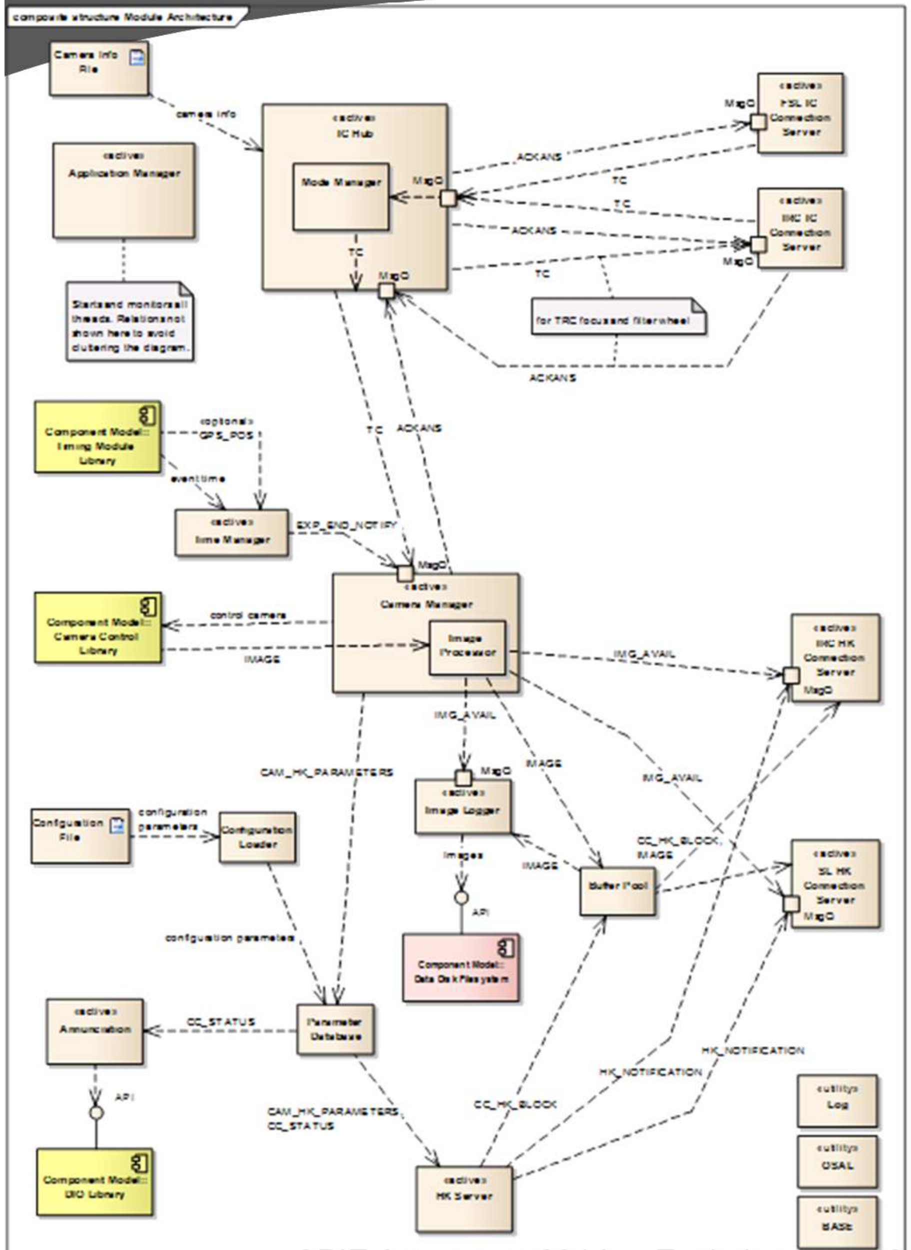
Embedded real-time Linux

Box format, PCI(e) slots

19“ rack mountable, PCI(e) slots

DIN rail mountable, mini PCI slots

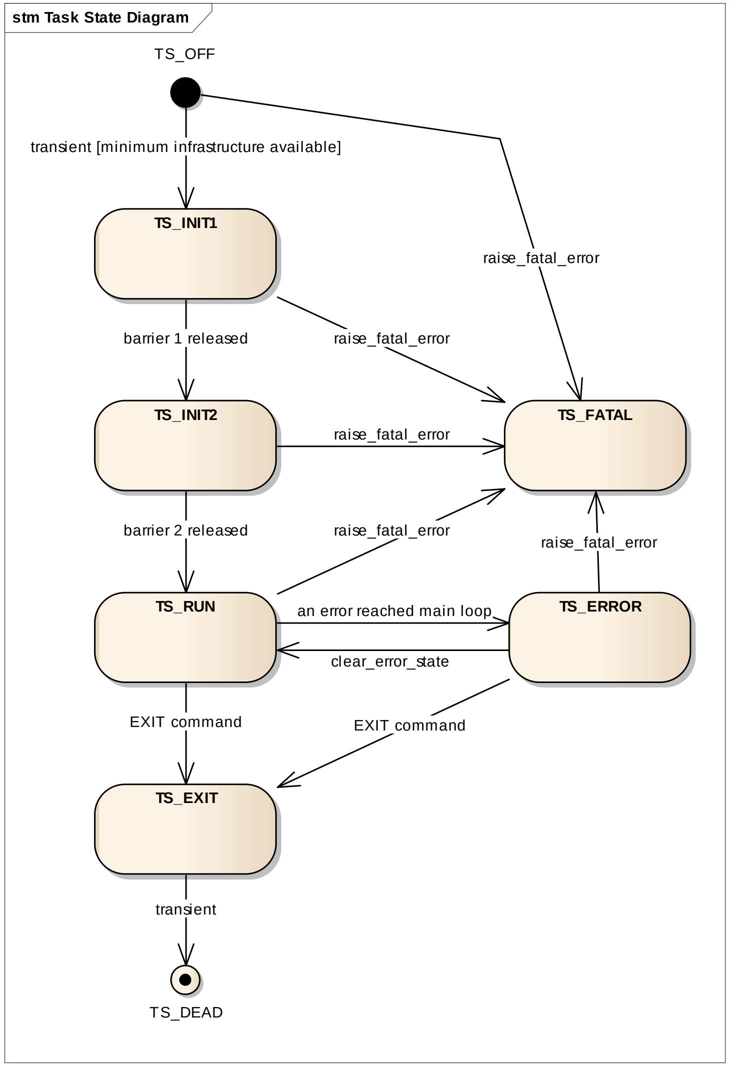
CC Application SW Development



- Object-oriented architecture, design and modelling with Enterprise Architect (Windows)
- Code generation and roundtrip engineering with Enterprise Architect
- IDE: Eclipse on Windows and Linux
- Compilation on same Linux kernel as the target
- CM with Subversion on Windows and Linux

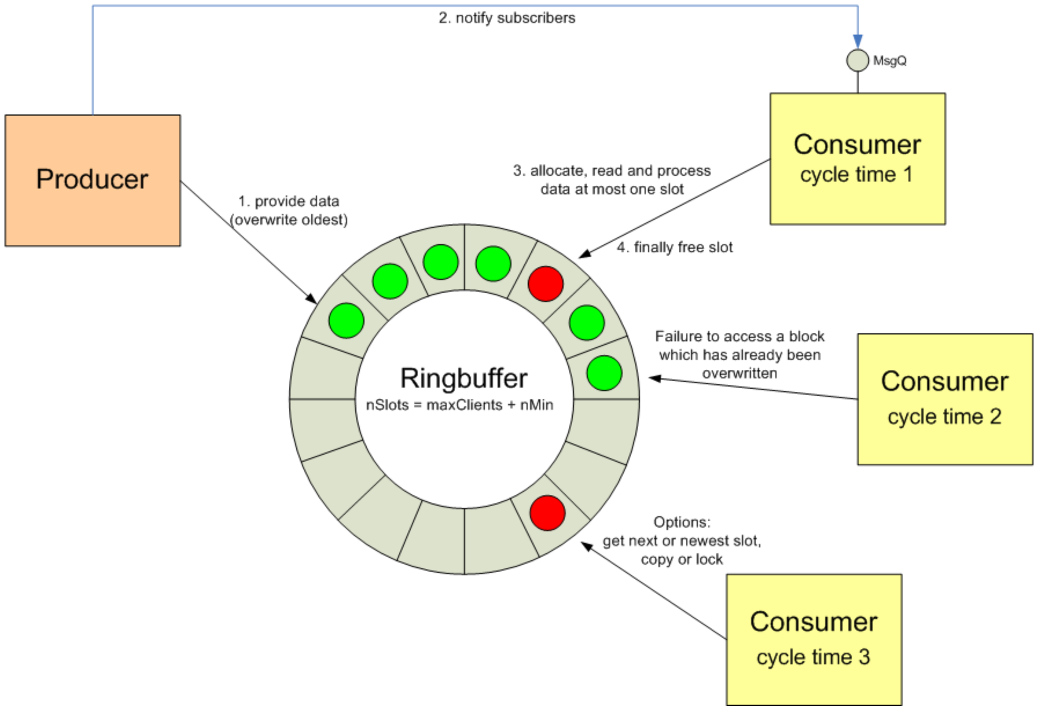
CC framework software

- object-oriented encapsulation and abstraction from basic OS resource; based on POSIX API
- process frame, including the default state machine, message-based event loop, error handling strategy and signal handling strategy
- event based, message notifications, and command/response



CC framework software

- In-core parameter database for configuration and data exchange; commands may be mapped on parameters
- BLOB (binary large object) pools for big data objects, like images or HK blocks; decouple process scheduling

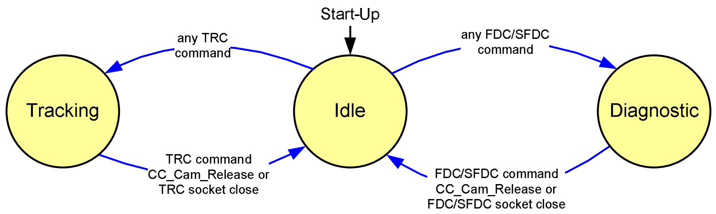


TCP socket tuning

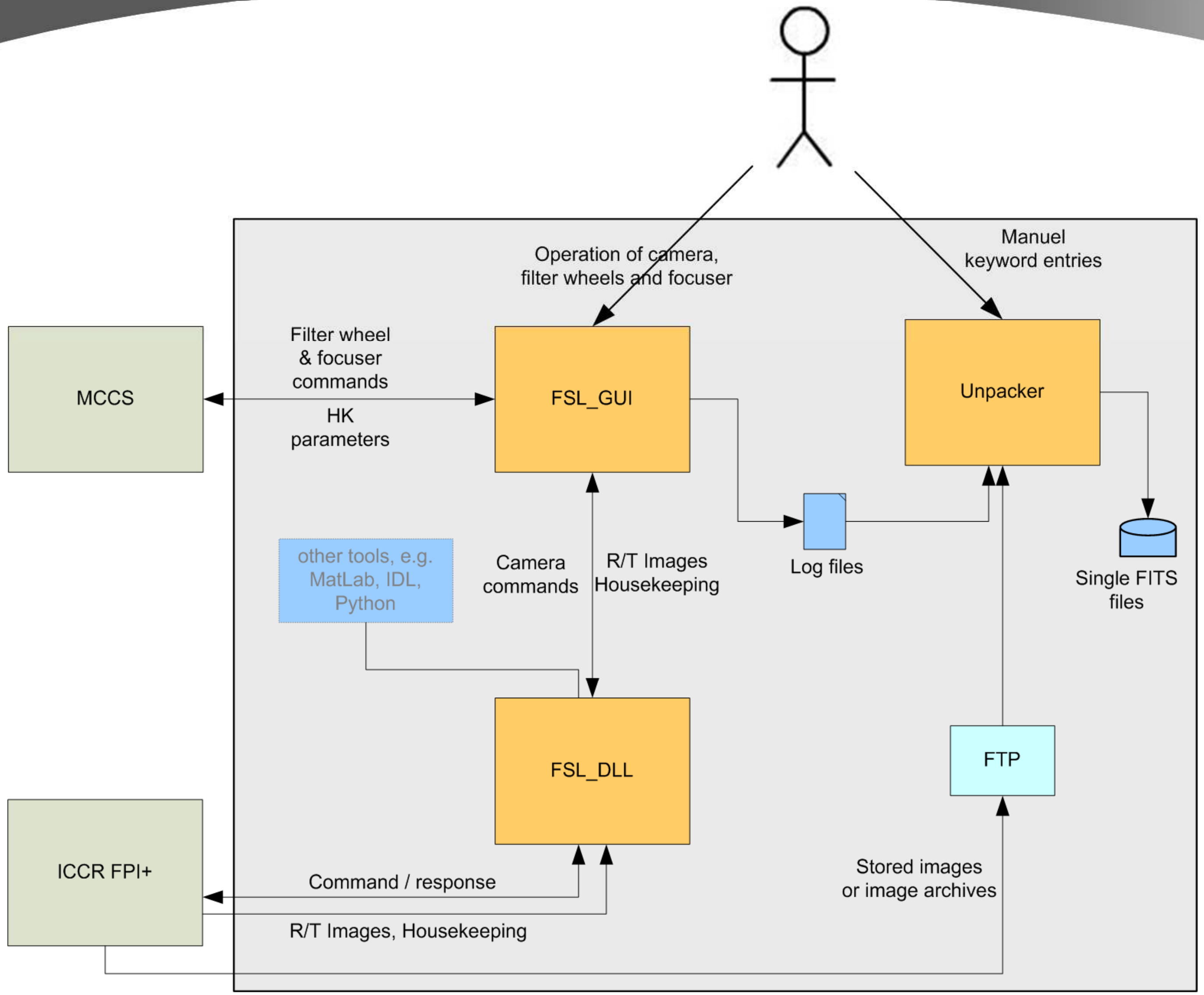
- Disable Linux signals for sockets
- Manage send and receive transactions in dedicated threads
- Enable TCP keep alive timer per socket and configure it to reasonable values
- Disable Nagle algorithm (TCP_NODELAY flag)
- Tune TCP retransmission timers
- Add ping/pong messages on application level; detect connection loss on receive timeout
- Tune socket buffers due to transmitted data

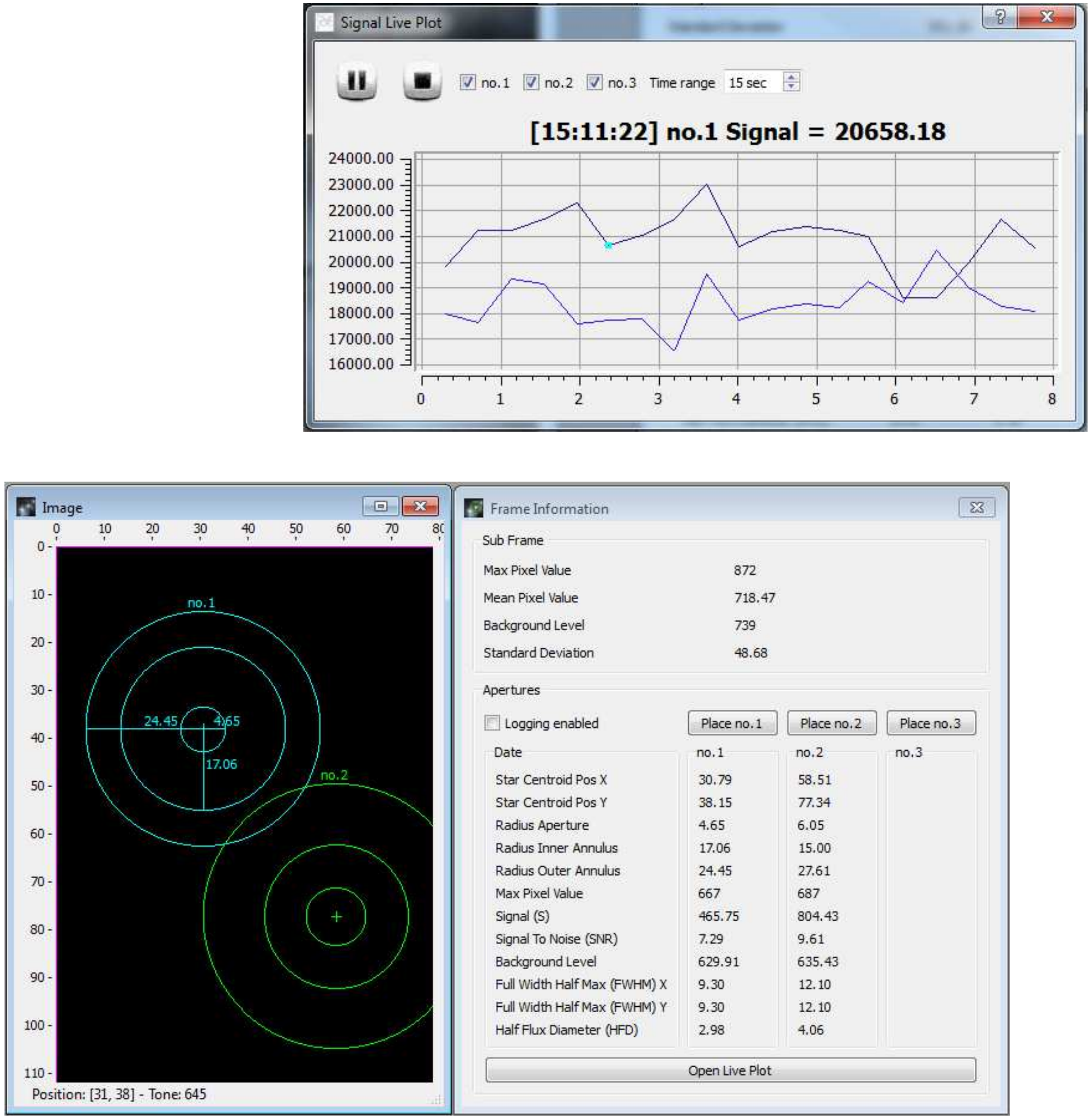
FPI+ as science instrument

- Motivation
  - Andor cameras are fast and very sensitive, up to 2 kHz acq. rate
  - FDC: measure pointing stability,characterize subsystems, like chopping with secondary mirror or mass damper system
  - Occultations, like Pluto together with HIPO
- Control concept
  - Partition between flight system (tracking) and science by HW and SW
  - Dedicated physical point to point network connections
  - Images and HK to both clients in parallel
  - Local image storage in FITS format or packed archives
  - Command mode state machine



FPI+ Science Operator Interface





FSL GUI screen shot – apertures and photometric evaluation

Summary

- The VME-based camera controller for the FPI has been replaced with an embedded Industrial PC; WFI and FFI will follow
- For the new camera controllers a dedicated Linux distribution has been set up
- A new camera controller software has been developed for Linux, needed parts of the old software have been ported
- The Tracker software architecture has been modified accordingly, though staying with VxWorks here for the time being
- The new camera controller software supports both, the technical use case for tracking and the scientific use cases of the camera
- Workstation software under Windows has been developed for the scientific use case