IFWG Memo: Enumeration of computer-controlled hardware

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OBJECTIVE

To enumerate all of the hardware that will be computer controlled in MROI. This is the initial step in producing a bottom-up costing of the computer hardware and in-consortium staff effort for both the top-level "Observatory" Control System (OCS) and in-subsystem controls.

SUMMARY

We have enumerated 16 distinct "configurations" of CPU needed for the MROI control system (each configuration runs distinct software and/or is interfaced to a distinct set of hardware). Multiple copies of many of these are required e.g. for 10 telescopes, giving a total of 84 CPUs in the interferometer. This number may be useful in costing computer hardware and software licences.

The *types* of control task required are listed below. Some CPU configurations must carry out more than one of these types of task. The bullets below may be a useful way of breaking down the man-effort.

Low-bandwidth

- Run the top-level "Observatory" Control System
- Subsystem simulator (no h/w)
- Read monitoring device e.g. vacuum gauge, temperature sensor
- Interface to a vendor-supplied Telescope Control System
- Open and close a telescope enclosure
- Control of rotation stage
- Control of kinematic slide
- Control of beam shutter
- Control of filter/dispersing element wheel in dewar
- Adjustment of optical component (1–5 axes per cpt)

High-bandwidth

- Run amateur CCD camera (up to 10Hz frame rate)
- Control of fast tip-tilt mirror
- Run low-noise CCD camera (up to 5kHz frame rate)
- Run low-noise IR detector (up to 5kHz frame rate)
- Control of delay line trolley (including active fringe tracking)
- Control of PZT path modulator

1. INTRODUCTION

For this document to be useful in producing a bottom-up costing, we must ensure that all of the different *types* of computer-controlled hardware envisaged for MROI are included (this drives the overall staff effort). We also provide information (e.g. total number of CPUs) that should be useful in costing the computer hardware.

The actuators etc. that are computer controlled, and perhaps the computers they are connected to *may* already be included in the overall costing for the project (i.e. not under the "interferometer controls" heading). Where the authors suspect this is the case, the relevant items are marked thus: ‡.

The section headings in this memo correspond to the headings in the System Budget document that is being prepared for the external reviewers. Some consequences of this structure are explained below.

We budget for 10 unit telescopes, plus spare components where appropriate.

2. CONTROL SYSTEM

The control system for the MRO Interferometer will consist of a central controlling unit, the "Observatory" Control System* (OCS), and a number of subsystems which communicate with the OCS and possibly with each other.

We prefer to adopt a "large subsystems" model for the control system (described in more detail in the earlier JSY/RCB/DFB memo), in which hardware is grouped into subsystems that (a) have a low-bandwidth connection to the OCS, and as few connections to other subsystems as reasonably possible, yet (b) are small enough to realistically be developed by a single contractor or in-house team.

As stated in the Introduction, we have adopted the section headings from the System Budget document for this memo. This structure should be the most helpful for preparing the interferometer costing. However, these headings are not particularly useful when thinking about the design of the control system, and do not correspond to its "large subsystems".

2.1. "Observatory" Control System

Requirements for the OCS are as follows (these are the more important of those listed in the October 2002 System Design document):

- The interferometer should be able to operate all night without human intervention, except for fault conditions, and possibly adverse weather conditions. This assumes an observing queue has been set up by an operator at the start of the night.
- It should be possible to control routine observing with the interferometer from a single terminal, probably running a graphical operator interface.
- It should be simple to install the operator interface on a new computer. Control of the array should not be limited to a particular terminal in the control room. It should be possible to perform routine operation via a low-bandwidth link.
- A limited amount of near realtime data analysis should be provided. This should be sufficient to judge how well the system is performing scientifically.
- OCS testing should be built in. Simulators should be available for all major or critical subsystems. This will allow testing of the OCS by simulating fault conditions in some subsystems. Initial simulators may be quite rudimentary.
- Subsystems should work autonomously where this makes sense. It should be possible to operate a subsystem in a useful manner even if no other subsystems are functioning.

We should cost a single CPU (plus a spare) to run the OCS software. Perhaps two additional CPUs will be needed to run subsystem simulators during the development phase — each of these CPUs will be able to run simulators for several subsystems at once.

Optical fibre network cabling and the associated hubs are budgeted elsewhere. We assume that there will be a fieldbus system that uses the same optical fibres.

*The OCS described here is specific to the MRO Interferometer.

- 1 CPU to run OCS, plus 1 spare
- 2 CPUs to run subsystem simulators

2.2. Monitoring

A range of monitoring equipment must be interfaced to the OCS. We assume passive temperature control for the beam-combining building.

- 3 vacuum gauges in relay system‡
- 1 vacuum gauge in delay system
- Bunker environment monitors (T, P, humidity, dust fraction)
- Weather station (costed under site-monitoring)‡

These sensors will all be interfaced directly to the ethernet or fieldbus system, so no extra cabling is required. If extra CPUs are needed to interface the sensors to the network, these must be added to the totals.

3. UNIT TELESCOPES

We assume these will be contracted out to a commercial supplier. The contracted-out work should include the control of the telescope drives and encoders, a pointing model, and any actuators and targets needed for the internal alignment of the telescope (e.g. focus control).

We will use an interface computer as an intermediary between the vendor-supplied telescope control system and the OCS. We assume that the vendor-provided system will exchange specified information with the interface computer via a simple custom protocol over ethernet.

Various ancillary equipment associated with the unit telescopes will be developed in-house; this is enumerated below:

- 11× (CPU to interface to TCS, also controls some of h/w below) (one per telescope plus 1 spare)
- 11× Ancillary CPU, controls remainder of h/w below
- 11× Sensors for T, P, humidity and dust fraction
- 11× Telescope enclosure (opening/closing thereof, dome rotation if applicable)
- 11× Wide-field pointing system: Starlight Xpress CCD camera (USB interface)
- 11× Tilt dispersion corrector: 2 rotation stages‡

To retain flexibility, we do not specify which of the above hardware is interfaced to which of the two CPUs.

Adaptive optics will be in Phase 2 so we don't have to cost it now. The fast tip-tilt systems will be located at the unit telescopes but are dealt with in the next section.

4. FAST TIP-TILT SYSTEM

We assume that the tip-tilt system doubles as the (narrow-field) source acquisition system. The CCD controllers and associated CPUs are listed in Section 8.

- 11× (2-position dichroic slide + 2-axis piezo-actuated mirror) (one set per telescope plus 1 spare)‡

5. BEAM RELAY

We assume a switchable relay system, as in the System Design of October 2002 (the light from a particular unit telescope can be directed down any of the relay pipes on the appropriate array arm). Note this is not completely flexible as we haven't budgeted for all of the pipes on a given arm extending to the furthest foundation.

Vacuum gauges are included in Section 2.2.

- 33× 4-position mirror on slide, connected to fieldbus system (one per station)

6. DELAY LINES

We assume a cats-eye retroreflector so there is no need for active azimuth correction. We assume no fixed delay lines (would need pop-up mirrors etc.)

- 1 master CPU
- 11× (1 embedded CPU + 1 motor + 1 D2A for voice coil + datum/buffer switches) (one set per trolley plus 1 spare)
- 3 laser interferometer systems (one per group of delay lines)

7. BEAM COMBINERS

We assume:

1. A fringe-tracking beam combiner, optimized for H-band operation. We don't budget for a switchyard as the relay system is switchable (this doesn't always get around telescope failure though)
2. Two four-way visible-wavelength (0.6–0.9μm) science combiners and a beam switchyard
3. Two four-way IR-wavelength (1.0–2.4μm) science combiners and a beam switchyard

The detectors and their controllers are enumerated in Section 8. In this section we consider the low-bandwidth control of the dichroic slides, beam switchyards, shutters, spatial filters, optical filters and dispersing elements needed during the night, as well as high-bandwidth control of PZT path modulators.

7.1. Fringe-tracking combiner

This combiner needs no shutters, switchyard, or spatial filters. J/H/K band is selected by a filter wheel. The dispersing element is fixed.

- 10 slides for dichroics
- 10 PZT path modulators
- 10 filter wheels (one per camera)
- 1 CPU to control above
- 1 CPU to run fringe tracking software. Talks to above CPU and to CPUs for fringe-tracker detectors and delay lines

7.2. Visible science combiners and switchyard

- 10 slides for dichroics
- 8 switchyard mirrors on 2-axis slides
- 8 PZT path modulators
- 8 beam shutters
- 8 3-axis positioners for spatial filters
- 9 wheels in dewars to select dispersing element (one per camera)
- 9 filter wheels in dewars (one per camera)
- 1 CPU to control above

7.3. IR science combiners and switchyard

- 8 switchyard mirrors on 2-axis slides
- 8 PZT path modulators
- 8 beam shutters
- 8 3-axis positioners for spatial filters
- 9 wheels in dewars to select dispersing element (one per camera)
- 9 filter wheels in dewars (one per camera)
- 1 CPU to control above

8. LOW-NOISE DETECTORS

We consider the tip-tilt/source acquisition detectors as well as the fringe detectors here. Detector readout must be synchronised with path modulation.

8.1. L3CCDs

Fast tip-tilt/source acquisition:

- 11 detector controllers (one per telescope + 1 spare)‡
- 11 Peltier coolers‡
- 11 CPUs for above‡

Visible science combiners:

- 9 detector controllers (one per beam-combiner output + 1 spare)‡
- 9 LN_2 cooling systems (probably monitoring only)‡
- 9 CPUs for above‡

8.2. IR detectors

Fringe-tracker:

- 10 detector controllers (one per 2 combiner outputs + 1 spare)‡
- 10 LN_2 cooling systems (probably monitoring only)‡
- 10 CPUs for above‡

IR science combiners:

- ➤ 9 detector controllers (one per beam-combiner output + 1 spare)‡
- ➤ 9 LN_2 cooling systems (probably monitoring only)‡
- ➤ 9 CPUs for above‡

8.3. Data analysis/archiving

Total data rates are predicted to be:

Fringe tracking detectors: 10 outputs $\times$ 4 spectral channels $\times$ 2 bytes $\times$ 200Hz = 16 kbyte/s

Visible science detectors: 8 outputs $\times$ 128 spectral channels $\times$ 2 bytes $\times$ 5kHz = 10 Mbyte/s

IR science detectors: 8 outputs $\times$ 128 spectral channels $\times$ 2 bytes $\times$ 5kHz = 10 Mbyte/s

We have budgeted (elsewhere) for a gigabit network. We therefore assume that a dedicated network for data transmission is not required.

Averaged (low-bandwidth) versions of the data stream must be available to the OCS and the alignment system.

- ➤ 2 CPUs + hard disks + archive devices (300 Gbyte/night)

9. ALIGNMENT SYSTEM

We assume that *all* optical components are computer controlled in the degrees of freedom that must be adjusted precisely. The actuators will be connected to the fieldbus system. Miniature beam-combiners should not require internal adjustment.

All of the alignment adjustments are low-bandwidth, and will usually be performed once per night or less frequently.

The total actuator count (may be underestimated) is:

- 30$\times$ tip & tilt‡
- 10$\times$ cats-eye focus‡
- 20 $\times$ *xyz*, tip & tilt‡
- 76$\times$ tip & tilt, *z*‡

The detailed list of components is as follows:

- ➤ (Internal alignment of unit telescope contracted out)
- ➤ 10$\times$ dichroic feeing tip-tilt system: tip & tilt
- ➤ 10$\times$ 2 relay mirrors: tip & tilt
- ➤ 10$\times$ delay line cats-eye: focus
- ➤ 10$\times$ 2 beam compressor mirrors: *xyz*, tip & tilt
- ➤ 10$\times$ dichroic feeding visible science combiner: tip, tilt, *z*
- ➤ 8$\times$ visible switchyard mirror: tip, tilt, *z*
- ➤ 8$\times$ visible detector feed: tip & tilt, *z* (if fibres)
- ➤ 8$\times$ dichroic feeding fringe tracker: tip, tilt, *z*

- 10× fringe tracker detector feed: tip & tilt, *z* (if fibres)
- 8× visible switchyard mirror: tip, tilt, *z*
- 8× visible detector feed: tip & tilt, *z* (if fibres)
- 8× IR switchyard mirror: tip, tilt, *z*
- 8× IR detector feed: tip & tilt, *z* (if fibres)
- 10? network cameras as alignment detectors
- 1 CPU to run it all