2. **Guidelines for CCD controller development.**	**SDSU**	**Copenhagen**
2.1 *Detector types* For the purpose of the analysis of requirements we have derived the following constraints on detector developments that will apply to a CCD controller:		
Visible detectors :- Predominantly CCDs. Clock structure, noise floor and output amplifier configurations will not change dramatically. Amplifier bandwidth will increase while retaining noise limits. Limit of 4 amps per CCD, possibly only 2 that can be utilized. Pixel sizes may reduce to a minimum of 7 æm, physical size may increase to a maximum of 8 Kpixels square. Mosaics will become more common.		
Infrared detectors :- NICMOS arrays to dominate, reduced noise from amps. Max. format 2 Kpixels square. Worst case data rate approx. 21 Megapixels / sec. across 4 output amps.		
Other detectors :- Solid state photon counters, active pixel devices, micro channel plate, and quantum detectors on the horizon. Need special requirements for controlling and are not considered in this review.		
2.2 *Detector usage* We contemplate the use of common CCD controllers for differing purposes in keeping with stated commonality objective. The purposes proposed for the CCD controller are:		
Science CCD imaging controller.		
Autoguider camera controller.		
Finder / slit view / direct television controller.		
Note: Television system may occasionally be used for autoguiding.		

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2.3 *System concept* Any development process on any sub system of the detectors (e.g. CCD controller) should contemplate the overall system effect keeping in mind a soundly developed **system philosophy** for the observatory. 2.4 *Controller Intelligence* The controller shall be considered as an integral part of a detector system. The level of intelligence should be limited to the **controlling and reading out** of the detector and ancillary functions, preferably leaving higher levels of coordination and interaction to other levels of the system. Post image acquisition processing should not be done in the controller sub system. 2.5 *Time scales* For ING purposes, CCD controllers with the required specifications of this document are required now. Coupled to the acquisition of advanced CCDs, this will bring the capabilities of the observatory into a technologically balanced and competitive position. We feel that the given specifications have a life cycle of at least five years. 2.6 *Impact on Telescope Instrumentation* For all detector system development, careful consideration must be given to any implementation that requires changes to existing optical instrument hardware or software. Stated another way, any CCD controller enhancements will preferably have a minimal impact on existing instrumentation and control systems.		

## 3. Generalized common requirements for CCD Controllers.	**SDSU**	**Copenhagen**

The present 'Dutch' controllers set the upper limit on acceptable values for the following points 3.1-3.4.

3.1 *Low Noise* Less than 0.7 lsb rms. contribution from output of CCD amp to acquisition data value.

3.2 *Minimal Cabling*

To reduce number of connectors and likelihood of cable / connector failures, reduce EMF and ground interference.

3.3 *Minimal Power* To reduce dissipated heat near (usually a) focal station.

3.4 *Small Size* To reduce weight and moment on telescope / instrument and to facilitate movements of cameras.

3.5 *Robust Construction*

To survive the harsh telescope environment and to extend the useful lifetime of the investment.

3.6 *Host Interface* The CCD Controller shall be controlled, directly or indirectly through an intermediate system, by an astronomer using a SUN Sparc type workstation as a user interface. The image data from the CCD controller will be sent to an intermediate system for preprocessing before being used by an astronomer using a Sparc workstation to review the images.

3.7 *Controller command response*

All commands, except were limited by external influences, should have a maximum cycle time of 50ms. Commands should be non-blocking and multi-tasked, i.e. a command should be capable of being accepted and possibly proccessed while prior commands are still being processed.

3.8 *Dead Time* That is time measured from the end of an integration to the time that a new integration can be started, should be kept to a

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minimum. Target time should be 20 seconds for an 4x2k EEV in “quick mode” equivalent. A secondary ‘dead-time’ measurement is that of from end of an integration to making the data available to the observer for display. This maybe up to 10 seconds longer than the previous dead-time (e.g. 30s for the 4x2k EEV). 3.9 *Zero Light Pollution* The controller shall not emit visible light during any phase of normal operation. 3.10 *Maintainability* The controller will allow and facilitate local fault diagnostics without requiring the complete detector system to be connected. As well, the controller should also allow remote diagnostics to be carried out over the command communication channel.		

4. Specific requirements for Scientific CCD controller.	**SDSU**	**Copenhagen**
4.1 Chip formats Single CCD, maximum format of 8K x 8K pixels, full frame mode, single CCD per controller.		
4.2 CCD Outputs Maximum of four outputs per CCD / controller.		
4.3 Vertical clocks Eight vertical drivers for highly capacitive loads (balanced, high current) being four groups of two phases each. Each group with two levels of presetable high / low voltages between +/- 12 volts (tristate clocking). Each driver individually controlled with 100ns timing resolution. Global slope control on both edges combined with active ring suppression would be nice. Very low DC ripple component.		
4.4 Horizontal clocks 16 horizontal and reset drivers with high speed, moderate current drives. Four groups of four phases presetable between +/- 12 volts. 20ns timing resolution.		
4.5 Bias voltages 16 individually presetable bias voltages, 8 with 0 - 30 volts, 8 with +/- 12 volts range. Very low DC ripple and noise components.		
4.6 Input sensitivity 1æv / ADU relative to CCD output at 9db gain selected. Four software selectable gains for 0, 3, 6, 9 db gains (1,2,4,8) in two stages. Normal operation would be at 3db gain giving approx. 2 ADU (4 e-, assuming 1æv / e- CCD gain) rms. noise (controller noise 6db down on CCD amp noise). Ideally electronic gain should be independent of readout speed.		
4.7 Dynamic Range 96db (16 bit) conversion. giving approx. 65K e-, 131K e-, 262K e-, and 524K e- equivalent dynamic range via gain selecting on a Tek 1024 CCD.		
4.8 Linearity < 1 lsb across 96db.		
4.9 Readout speed Four software selectable pixel rates from seven preset (preprogrammed) values of 10, 20, 50, 100, 200, 500, 1000, [2000] Kpixels / sec / output. Not all of these rates will be applicable to any given CCD, the		

set of most efficient rates should be preset for any CCD / instrument combination. It is noted that it will be difficult to achieve near optimum operation of the amp coupling and cds across 2 decades of integration period. An alternative is to have two component setups for the amp / cds / adc boards accommodating 1 decade each that can be selected for each particular CCD. Note: two Megapixel / sec readout speed is desired but is not a hard requirement.	**SDSU**	**Copenhagen**
4.10 <u>Windows</u> 4 user definable readout windows that can be simultaneously active.		
4.11 <u>Binning</u> allow independent x y binning without compromise to linearity or noise, maximum 64 pixels binned. Binning and windowing must be available simultaneously		
4.12 <u>Temperature control</u> Proportional control to provide analog servo through resistive heater element for maximum of 5 watts. Temperature stability to be 0.2ø with reading and setting resolution of 0.1ø. Software programmable servo setpoint. Two reading channels for platinum resistors, one used for servo feedback plus one channel for diode type sensor for LN2 expiry alarm. Provision for gas flow sensor input with presetable alarm for low flow. Integral warm up / cool down cycle control to prevent condensing matter.		
4.13 <u>Time stamping</u> All images should carry local controller time information indicating time of shutter open and time of shutter close with 1ms resolution and 100ms accuracy. Provision for GPS time service synchronization should be made. Provision should be made for accepting external synchronization of readout (slave mode) and generating readout sync output (master mode).		
4.14 <u>Operational modes</u> All modes should take into account the geometry of the chip, the number and location of readout amps to be used and any window / binning settings. <u>Service modes</u> to provide CCD conditioning should be: Clear (wipe) once, clear		

continuous, Preflash, Open shutter, Close shutter. Integration modes should be: Antibloom clocking. Readout modes should support: Full frame readout, drift line readout, focus readout, readout on sync. Maintenance modes to facilitate control and confidence testing should provide the following services: Report controller status, Report CCD status, Download / report telemetry values, Download / report CCD device description block, Download / report integration block, Reset system. 4.15 Preflash One constant current source (hardware preset between 0.5ma and 15ma) with software selectable time between 1ms - 65 seconds. 4.16 Shutter control Provision for pulse and level control drivers programmable via software, provision of two sense inputs for shutter open, shutter closed status. Provision of local control and status indication. Provision for automatic sensing of shutter type.	**SDSU**	**Copenhagen**