**Po-045**

# System design of the South African Lunar Laser Ranger

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## Abstract

*The development of a Lunar Laser Ranging (LLR) system for South Africa is progressing well. During the system design phase attention was given to incorporate ideas that worked at other laser ranging stations, as well as avoid things that proved to be problematic. An overview of both our rationale of system design as well as the current LLR design, depicting the developmental state of different components, is discussed.*

## Introduction

A new Lunar Laser Ranger (LLR) is currently under development at Hartebeesthoek Radio Astronomy Observatory (HartRAO), South Africa. The primary system goal is to achieve sub-cm LLR normal points and the system will be utilized for various other tasks like Satellite Laser Ranging (SLR), time transfer experiments and laser deep space communication. This LLR is a completely new system except for the 1m optical telescope which was donated by Observatoire de la Côte d'Azur, France.

## System design

Our fundamental design rationale can be summarized as:

- General: The top-level system design must be as simplistic as possible and can be expanded in complexity as required at a later stage. The system should be fully software controllable, both from a local interface as well as remotely. Components off The Shelf (COTS) should be utilized whenever it is available within the required specifications.
- Power: An on-line UPS backup power must be used for all control systems; battery backup for the servo controllers at the telescope will prevent encoder positional data loss during power outages.
- Connectivity: Fast internet connectivity for both incoming and outgoing connections with auto-failover is required. System remote control access should also be managed at this level.
- Communication: A high-speed low-latency, single protocol interface should form the communications backbone between subsystems.
- Data storage: Central application and data storage in RAID Network Accessible Storage (NAS) device will ensure integrity and minimize downtime due to storage- or PC failure.
- Control System: A software-centric system linking via microprocessors at different interface locations is required. This system is developed in-house.
- Environmental Control: Control building inside temperature control to within 2º C is required, clean-room conditions for the laser room, automated run-off enclosure for telescope.
- Diagnostics: Separately controlled independent diagnostics system. COTS hardware and software will be used here. Critical conditions will set off alarms, send emails and a text to cellphones of operators and managers.

- Software: An in-house package for system control and analysis is under development. Commercial / open source software will be used for visualization (eg. Excel).
- Timing: The HartRAO H-maser (which is used for VLBI) will steer local system time systems together with 1 PPS and an NTP server. Precision Time Protocol will be implemented at critical hardware systems.
- Laser: Separate and independent laser systems for LLR and SLR to be supplied by the NASA contractor. We have the option to increase output power at a later stage.
- Telescope drives and control: COTS hardware which is directly controllable by our in-house software is required. The system should be able to operate in velocity profile mode.
- Return pulse detection: An all-in-one high accuracy low jitter package is required.
- Calibration - Internal: A common optical path for both lasers should be used as far as possible. The control and diagnostic systems must be located directly at the interface point.
- Calibration - System tie: Daily local ties with the VLBI antennas, SLR, LLR, GNSS and reference piers will be done with an automated theodolite.

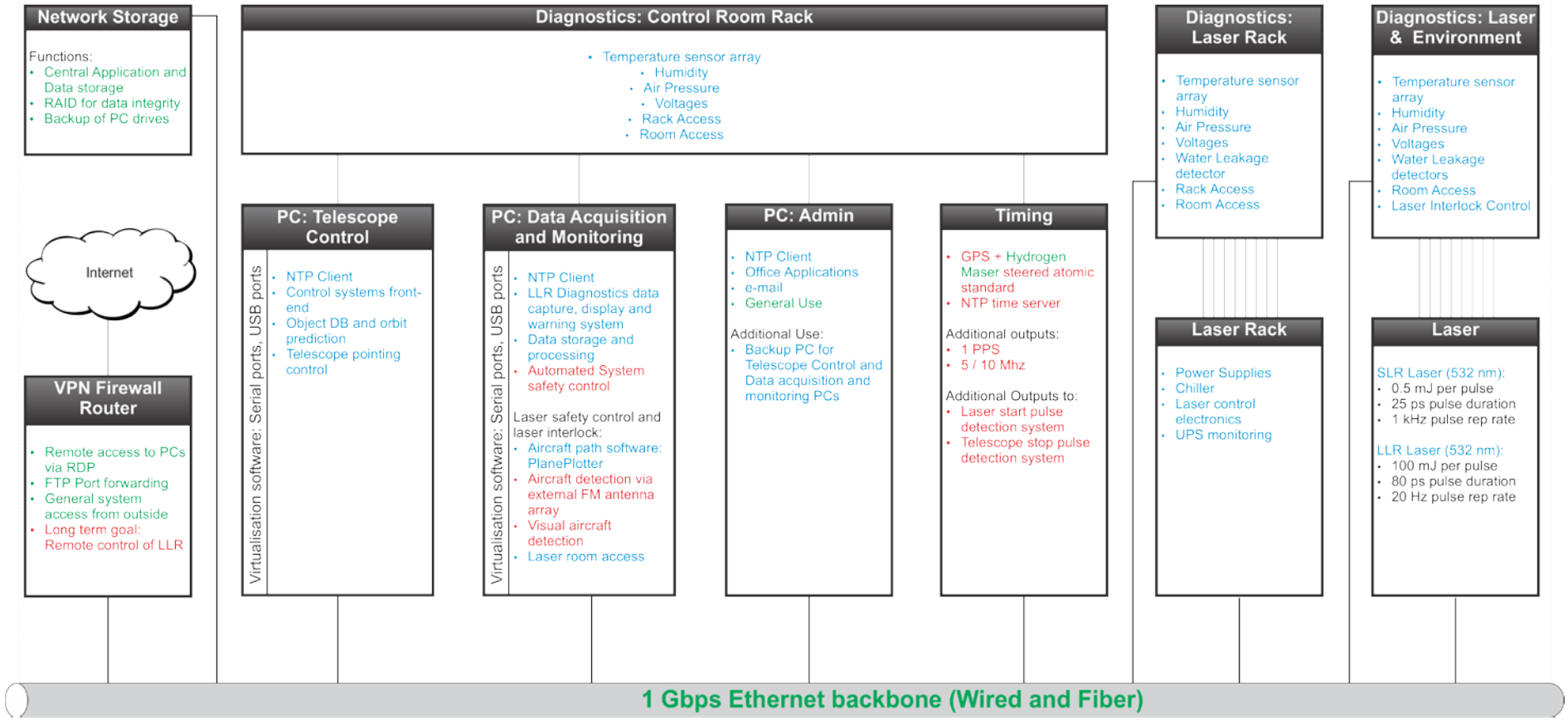
Implementing industry-standard systems, communications and interlink protocols are of utmost importance since it will both reduce initial development time as well as ensure long-term component (and therefore support) availability. These approaches allow us to place equipment directly where it must measure or provide signals, rather than in one large control room. This drastically cuts down on cabling, potential timing calibration problems and the number of different interfaces that must be interacted with.

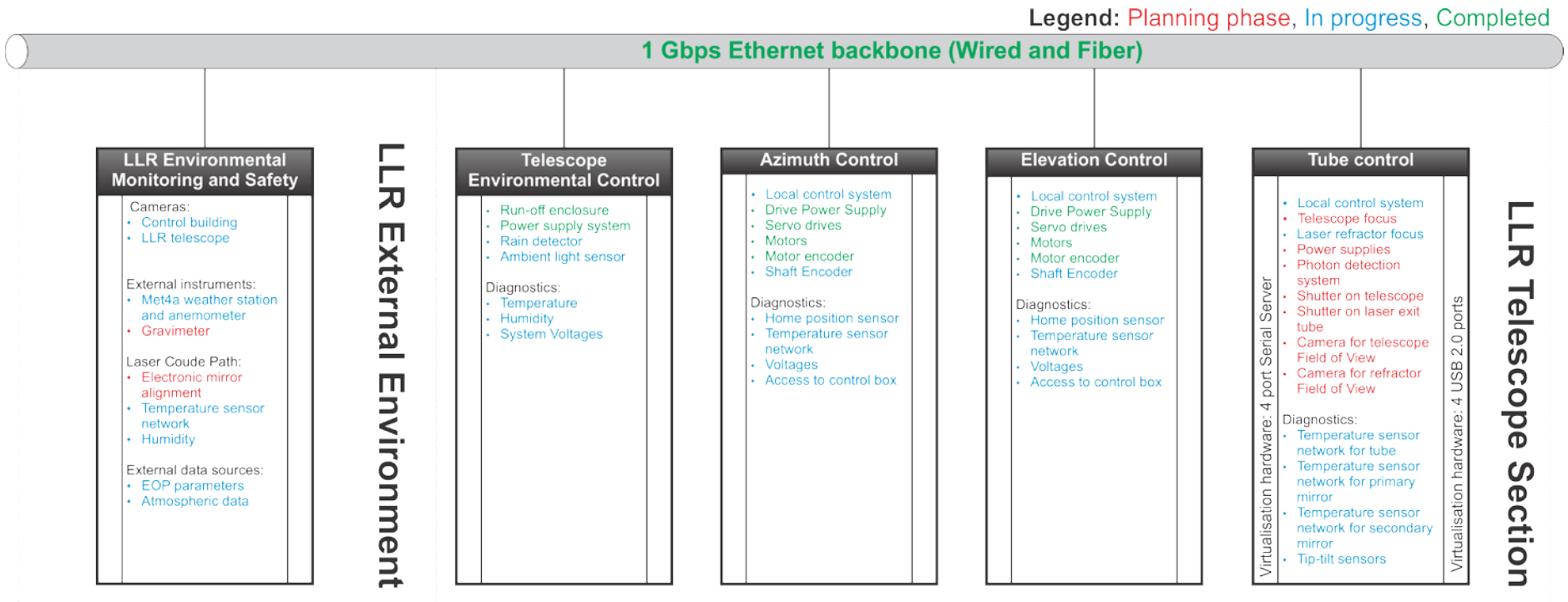
Central software control systems are being developed in-house to monitor and control the complete laser ranging system from the control room as well as remotely via the internet. The software-centric approach is implemented by sharing data between applications using DDE. Multiple monitors will give an instantaneous overview of all system parameters and are controllable via a single keyboard and mouse. A central logging database will be used for record keeping and troubleshooting.

Figures 1 and 2 depict the system layout and design, as well as the developmental state of each component.

# LLR Control building

**Legend:** Planning phase, In progress, Completed




Legend: Planning phase, In progress, Completed
1 Gbps Ethernet backbone (Wired and Fiber)
LLR Environmental Monitoring and Safety
Cameras:
• Control building
• LLR telescope
External instruments:
• Met4a weather station and anemometer
• Gravimeter
Laser Coude Path:
• Electronic mirror alignment
• Temperature sensor network
• Humidity
External data sources:
• EOP parameters
• Atmospheric data
LLR External Environment
Telescope Environmental Control
• Run-off enclosure
• Power supply system
• Rain detector
• Ambient light sensor
Diagnostics:
• Temperature
• Humidity
• System Voltages
Azimuth Control
• Local control system
• Drive Power Supply
• Servo drives
• Motors
• Motor encoder
• Shaft Encoder
Diagnostics:
• Home position sensor
• Temperature sensor network
• Voltages
• Access to control box
Elevation Control
• Local control system
• Drive Power Supply
• Servo drives
• Motors
• Motor encoder
• Shaft Encoder
Diagnostics:
• Home position sensor
• Temperature sensor network
• Voltages
• Access to control box
Tube control
Virtualisation hardware: 4 port Serial Server
• Local control system
• Telescope focus
• Laser refractor focus
• Power supplies
• Photon detection system
• Shutter on telescope
• Shutter on laser exit tube
• Camera for telescope Field of View
• Camera for refractor Field of View
Diagnostics:
• Temperature sensor network for tube
• Temperature sensor network for primary mirror
• Temperature sensor network for secondary mirror
• Tip-tilt sensors
Virtualisation hardware: 4 USB 2.0 ports
LLR Telescope Section