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Comprehensive Safety Analysis for Cassegrain U-Band Spectrograph in the scope of FDR

Mina Sibalic[*a,], Vincenzo De Caprio[a], Domenico D'Auria[a], Matteo Genoni[b], Roberto Cirami[c] and Stefano Covino[b]*

[a]*INAF – Osservatorio Astronomico di Capodimonte, Salita Moiariello 16, 80131 Napoli, Italy*
[b]*INAF – Osservatorio Astronomico di Brera, via Brera 28, 20121 Milano, Italy*
[c]*INAF – Osservatorio Astronomico di Trieste, Via G.B. Tiepolo, 11 I-34143 Trieste, Italy*

INTRODUCTION

CUBES (Cassegrain U-Band Efficient Spectrograph) is a high-efficiency VLT class Instrument, a two-arm spectrograph, aimed at observing the sky in the UV ground-based region (300 - 400 *nm*) with a spectral resolution up to ~ 20K. CUBES consists of nine subsystems functionally divided into four macro-assemblies.

The macro-assemblies of CUBES are categorized based on the functional perspectives of the subsystem. The electronics subsystem is responsible for all the system control functions, except for those related to the scientific detector system and the associated cryo and vacuum system.

CUBES light path gathers all the items that elaborate light coming from either the scientific objects or the calibration sources, depending on the procedure CUBES is set to perform. The calibration subsystem will provide the light sources for daytime calibrations and the Active Flexure Compensation system (AFC).

Detector and cryo-vacuum systems require two science detectors, installed in two identical cryostats, and items to operate them.

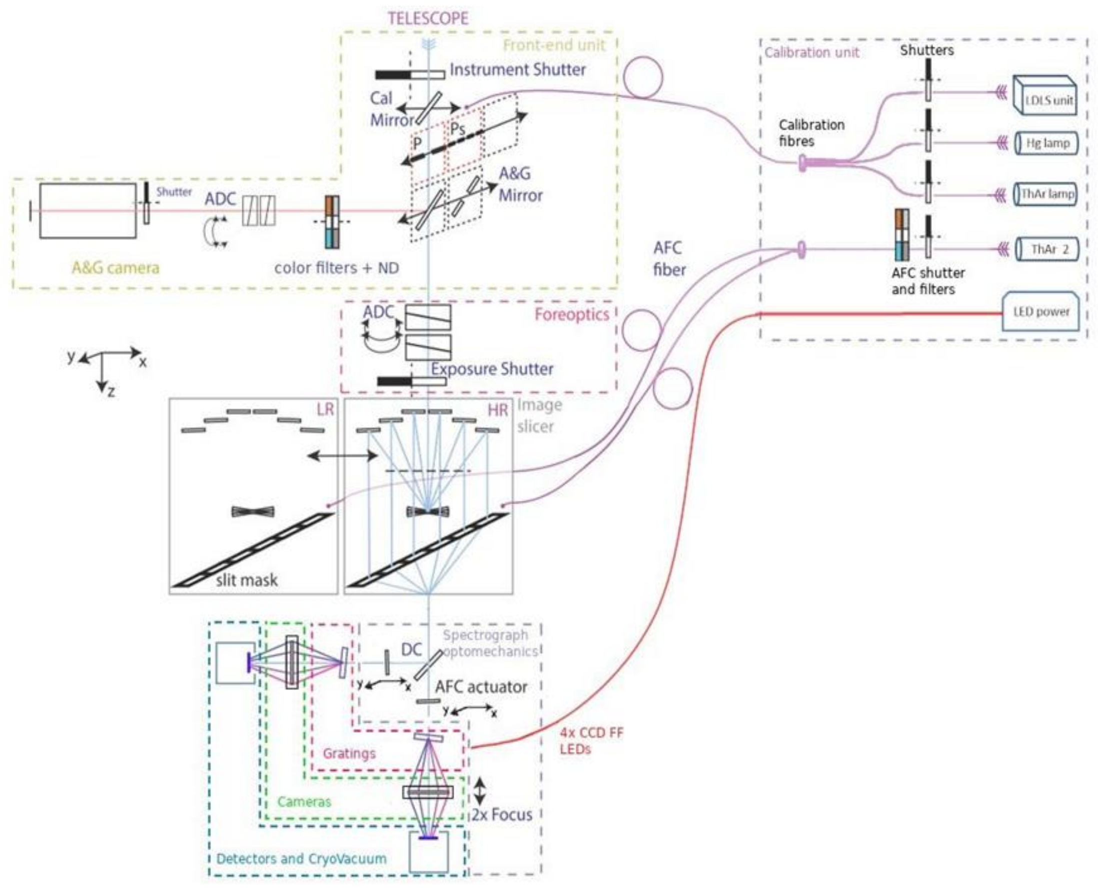

Figure 1. CUBES scheme

CUBES Hazard Analysis aims to pinpoint potential risks and hazards linked to it within its operational setting. Hazards have different sources and effects. In this study, hazards are classified by origin.

Hazard groups that are analyzed in terms of severity, probability, and detection are:

1) Mechanical hazards,
2) Electrical hazards,
3) Thermal hazards,
4) Material/Substance hazard,
5) Radiation hazards.

METHODOLOGY

This assessment facilitates a clear comprehension of the necessary measures to mitigate dangers and risks posed to humans, products, and operations throughout different life cycle phases.

Defined CUBES life cycle phases which are considered in this analysis are:

a) Manufacturing, Assembly, Integration, and Testing (MAIT);

b) Shipping;

c) Storage;

d) Re-assemble/Installation;

e) Observation;

f) Maintenance.

In implementing safety protocols, the first step is identifying potential hazards that could endanger personnel or equipment. By prioritizing the implementation of effective safety protocols, the risk of accidents and damages can be minimized, ultimately contributing to the successful and secure operation of the CUBES spectrograph.

Figure 2. Methodological Sequence of the Hazard Analysis

Risk mitigation strategies apply the "STOP" hierarchy. This strategy provides substitution (or removal) of the hazards, technically mitigating an acceptable risk level and determining what

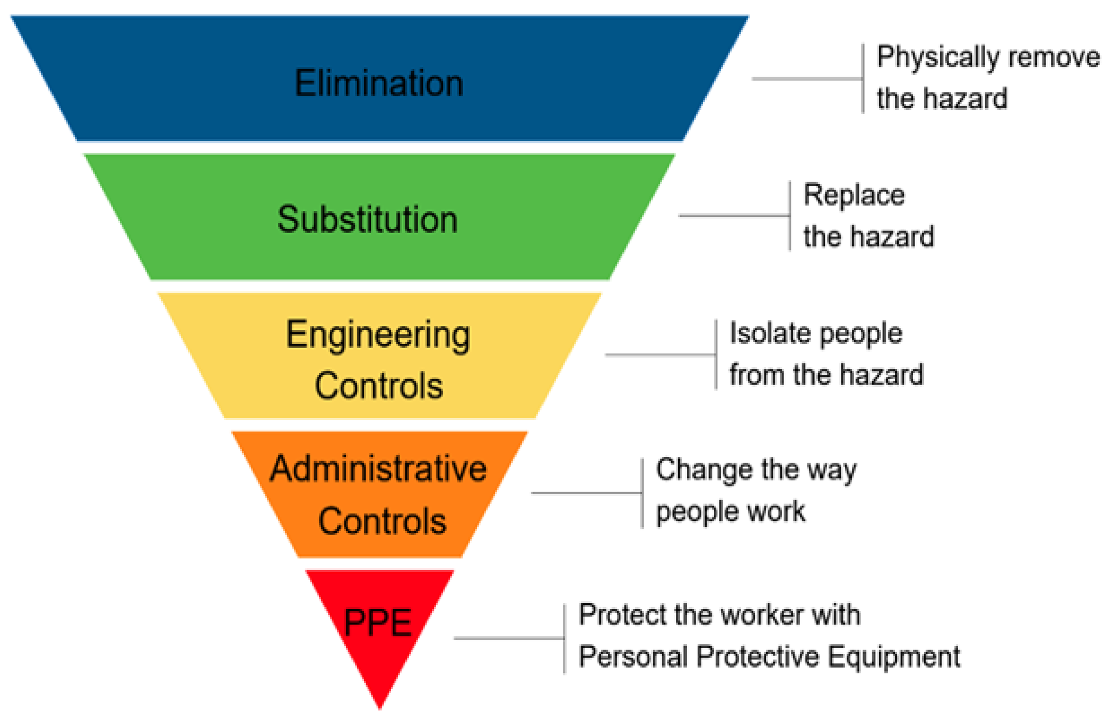

Figure 3. Risk Mitigation Strategy

RESULTS

In the following Figure 4. is an extracted table from the CUBES Hazard Analysis, presenting only the hazards that after the mitigation don't have an "Acceptable" score, but the score that requires explanation.

Hazard list			Preliminary Hazard Analysis				Hazard Analysis after mitigation			
Nr.	Hazard origin		Before Mitigation				Mitigation	After mitigation		
			S	P	R			S	P	R
M-3	Loss of stability of the instrument (or parts of the instrument)	H	1	D	1D		Use of a crane or ad hoc tool to lift the components. Only trained personnel are authorized to operate. PPE used by personnel	2	D	2D
		P	1	D	1D			2	D	2D
		O	/	/	//			/	/	//
M-4	Falling objects	H	1	D	1D		PPE used by personnel.	3	D	3D
		P	1	D	1D		Suitable tools to avoid loss of control	2	D	2D
		O	/	/	//			/	/	//
E-10	Electrical hazard due to liquid	H	1	C	1C		Proper design: isolate water and electrical circuits where possible, cooling junctions far from/below electrical circuity (if not feasible, use of IP41 electrical connectors), leakage sensors along the hoses, and use of metallic pipping wherever possible. Pressure test before operation. Hoses preventive maintenance.	1	E	1E
Mat-1	Ethylene glycol toxicity	H	1	D	1D		PPE masks	1	E	1E
		P	/		//			/	/	//
		O	/		//			/	/	//

Figure 4. Extracted Hazards from the Risk Assessment matrix for Mechanical, Electrical, and Material/substance hazard

All five groups of Hazards have been analyzed, and hazards have been eliminated or the risks have been reduced to the acceptable level with extensive evaluation.

The number of "Unacceptable" hazards before and after mitigation went from twenty-one to zero.

After the calculation and analysis, it was determined that no Hazard needs SIL certification.

CONCLUSION

Collectively seventy hazards have been identified and assessed. After mitigation sixty-five of them are "Acceptable". Five hazards could be technically mitigated to an acceptable risk level, but not eliminated, and they fall in the "Acceptable with review" risk category. Those risks show that:

1. After mitigations, there are no risks to humans, but the Instrument itself cannot always be protected.
2. Contact between leaked liquid and electrical components could lead to a catastrophic risk for humans.
3. Ethylene glycol is a toxic substance, therefore personnel must wear masks during operations on the cooling system.

[*]**Contact Author: mina.sibalic@inaf.it**

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