System Engineering

NectarCAM Progress Meeting, 6 & 7 April 2021

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System Engineering: Agenda

- CDMR Recommendations
  - MST Structure-Camera Interfaces & other External ICDs
  - Requirement Management and Design Verification
- Status & on going actions

Syst. Eng. CDMR Recommendations

- **High priority: should be completed as soon as possible and prior to start procurement**
  - NectarCAM shall complete the work needed to demonstrate conformance with applicable EU Directives with the support of the CTAO Product Safety engineer (#42329).
  - NectarCAM and MST structure teams need to complete the external interfaces with the MST structure and resolve the mass non-conformance (#42380).
  - The panel supports the approach proposed by NectarCAM to apply EN 13659:2015 to verify the compliance of the shutter with the environmental requirements and recommends the MST teams and CTAO work to find an acceptable solution.
  - CTAO and camera teams need to complete the other external ICDs such as with ACADA and the array clock system. The NectarCAM team need to demonstrate compliance of the NectarCAM design with the applicable interface requirements.
  - NectarCAM project team need to demonstrate that there is negligible technical risk in their proposal to proceed with hardware procurement before the development of the control software has been fully defined (#42335).
  - The verification plan needs to be released (#42850) and the design compliance demonstrated in an updated verification matrix (#42745).

- **Normal priority: to be completed before the first acceptance review**
  - Draw up specifications for chiller (#42334)
  - Add description of maintenance access platform and write missing ICD (#42381)
  - Power budget : check consistency between documents (#42647)
  - Design non compliances: trigger deadtime > 5% (#42413), commercial components not specified to be compliant to the altitude requirement (#42520).

External Interfaces with MST-Structure

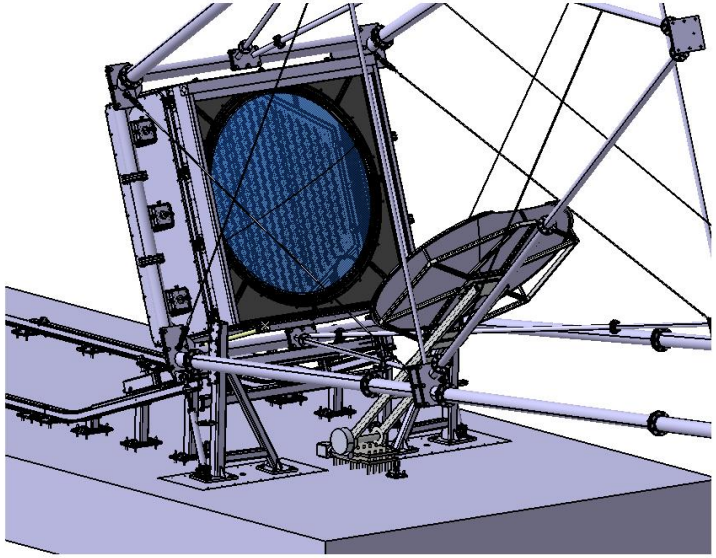
- Many recommendations related to External Interfaces with MST-Structure
  - Camera weight limit
  - Camera shutter and high wind protection system
  - (Common) Chiller Specification
  - Power Budget
  - Safety Interlock
  - Maintenance tools (including maintenance tunnel, Camera Mounting System)

- Ongoing Actions
  - Weekly meeting within MST TCG (MST Technical Coordination Group)
  - Includes people from MST Structure, FlashCAM & NectarCAM
  - Aim to complete the MST Structure-Camera ICD by June 2021

External Interfaces with MST-Structure: Status

- Camera weight limit
  - NectarCAM estimated at 2,2T while interface limit defined at 2T
  - Issue in case of seismic load
  - FlashCAM mass: 2,05T but needs be reinforced (shutter + structure).
  - Cameras have been asked to check if weight reduction is possible
  - -137 kg estimated for NCAM for Camera n° 2 & followings
  - Possible reinforcement or amortization of Telescope Structure studied

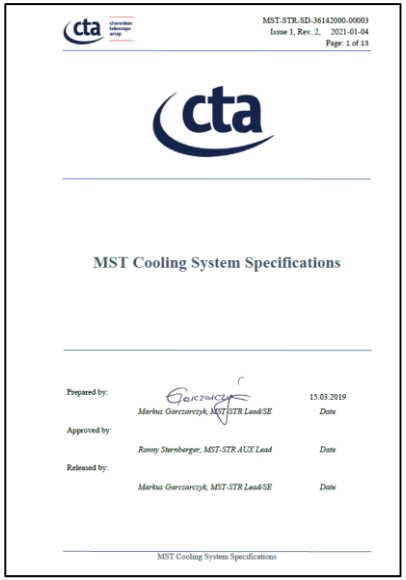
- Camera shutter and high wind protection system
  - NCAM shutter has not demonstrated its compliance with CTA environmental requirements yet (200km/h wind gust)
  - A wind test is foreseen
  - LST shutter performances taken in consideration too
  - In case NectarCAM and LST shutters fail to pass class 5 requirement, an on-ground wind protection system is envisionned. At the time being, no final design, neither human resource available
  - CTAO concerned by reliability aspects



A concept of on-ground wind protection system

External Interfaces with MST-Structure: Status

- Chiller Specifications
  - Common chiller for camera, telescope UPS and drive
  - List of specifications established
  - Being revised by experts (DESY experts + external company)
  - CTAO agrees to procure the shutter if funds covered by MST
- Power Budget
  - Structure and camera power budget revised and shared with CTAO
- Safety Interlock
  - List of safety relevant points being identified with a focus on interactions between telescope structure & camera
  - In contact with CTAO Safety Engineer. Expected at Saclay asap
- Maintenance tunnel
  - Degradation of PMT & Plexiglas window performances with sun
  - Maintenance tunnel required for camera front maintenance
  - Design maturity versus environment to be demonstrated
  - On site workshop (re)discussed with CTAO


MST-STR-SD-36142000-00003
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MST Cooling System Specifications

Prepared by: Marius Garczarczyk, MST-STR Lead/SE — 15.03.2019 Date
Approved by: Ronny Sternberger, MST-STR AUX Lead — Date
Released by: Marius Garczarczyk, MST-STR Lead/SE — Date

MST Cooling System Specifications

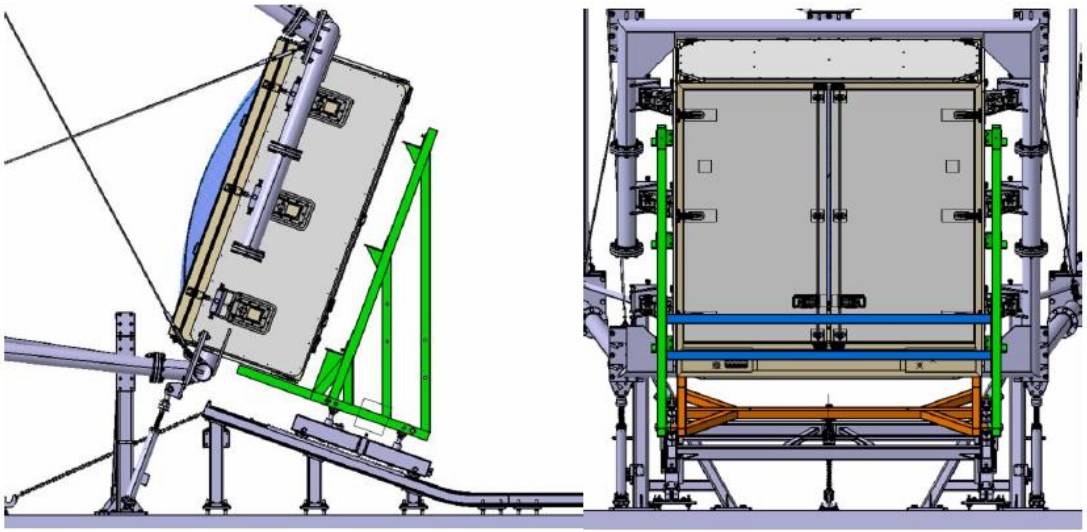
MST Cooling System Specifications


Maintenance Tunnel used at Berlin

External Interfaces with MST-Structure: Status

- Camera Mounting System (camera trolley)
  - Camera loading & unloading system design available
  - Details being tuned

- Maintenance tools
  - Usage of boom lift considered too risky
  - Front maintenance: camera will be unloaded and maintenance done under the tunnel (expected ~ every 2,5 year)
  - Rear Maintenance: most performed while camera in parking position. Interface of maintenance platform/trolley to be defined



CAD views of the setup behind the NectarCAM camera during maintenance

Other External Interfaces

- Recommendations
  - CTAO and camera teams need to complete the other external ICDs such as with ACADA and the array clock system. The NectarCAM team need to demonstrate compliance of the NectarCAM design with the applicable interface requirements.
  - NectarCAM project team need to demonstrate that there is negligible technical risk in their proposal to proceed with hardware procurement before the development of the control software has been fully defined (#42335).

- Status
  - List of External interfaces have been completed
  - List completeness to be agreed with CTAO
  - Several interfaces being discussed currently with ACADA
    - ACADA - Camera_Event_ICD
    - ACADA - Array Element Logging ICD
    - …
  - Compliance of NectarCAM design with external interface requirements to be demonstrated, as well as the “negligible technical risk” to proceed with hardware procurement before the development of the control software.
    - Camera control demonstrated during Adlershöf Campaign
    - Very similar to LST
    - Complete camera readout scheduled in May to validate DAQ switches

REQUIREMENT VERIFICATION

CDMR Recommendations & Reminder

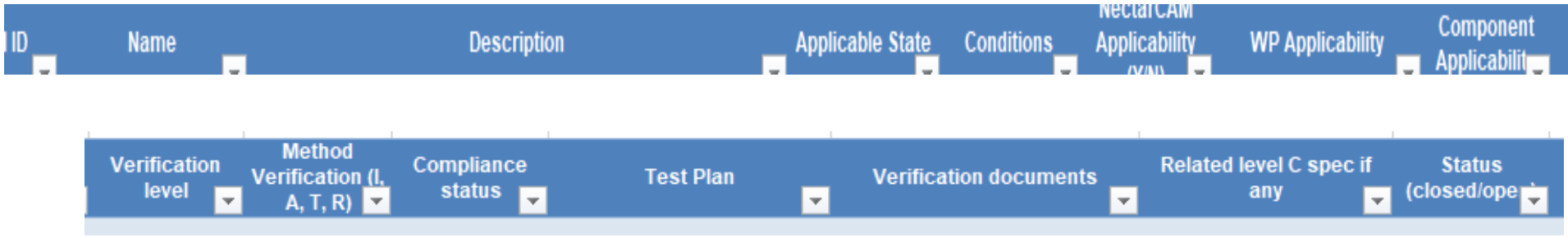
CDMR Recommendations:

- The verification plan needs to be released (#42850) and the design compliance demonstrated in an updated verification matrix (#42745).
  - “Formal flow-down to lower-level requirements has not been provided and the panel struggled to understand the status of design verification ”
  - “No specification tree was provided”
- NectarCAM to provide a preliminary list of design verification tests that will be performed on QM (#42646)

Reminder:

- Flow down based on paper work, since JAMA sustainability was not guaranteed since 2018
  - NectarCAM requirement verification demonstration based on the NectarCAM Verification Matrix
  - And at workpackage level: Requirements & Specifications document, Performance Verification Document, WP Verification Matrix

NectarCAM Verification Matrix



ID	Name	Description	Applicable State	Conditions	NectarCAM Applicability (Y/N)	WP Applicability	Component Applicabilit

Verification level	Method Verification (I, A, T, R)	Compliance status	Test Plan	Verification documents	Related level C spec if any	Status (closed/ope

tem | Produced by: | Julie Prast | CTA Requirements (current structure)

Environmental Requirements | on: | 26/11/2018 | Cherenkov Telescope Array Observatory

Global	Name	Description	Applicab State	Conditio	Require at Stat	NectarC Applicab	WP Applicabili	Compos Applica	Verificat level	Method Verificati	Complian status	Test Plan	Verification documents	Related level C s	Status	Comments
CTA-200712	B-ENV-0625 Survival ice load (South)	Damage beyond the Serviceability Limit State must not occur due to an ice thickness (on all surfaces) of up to 20 mm.	All		Stable	Y	Mech&Cooling		Mech&Cooling	Analysis or Simulation	Compliant		CTA-LLR-TN-0021_Camera Structural Analysis	C-MST-CAM-NC-0054	Closed	
CTA-200128	B-ENV-0710 Observation Wind Speed	Performance requirements for observations must be met under 10 minute average wind speeds of up to 36 km/h	Observing	Observing	Stable	Y	Mech&Cooling		Structure	Tests	Compliant		CTA-LLR-TN-0021_Camera Structural Analysis		Closed	
CTA-200131	B-ENV-0720 Transition Wind Speed	During transitions, damage must not occur on-site due to 10 minute average wind speeds of up to 50 km/h and damage beyond the Serviceability Limit State must not occur due to 10 minute average wind speeds of up to 60 km/h.	Transitional	Transitional	Stable	Y	Mech&Cooling		Mech&Cooling	Analysis or Simulation	Compliant		MST-CAM-SP-0456-CENBG-LP2IB: NectarCAM Front Door Requirements		Closed	Shutter can be closed with winds up to 50km/h (class 3) C by design.
CTA-200132	B-ENV-0730 Survival wind speed (North)	Damage must not occur at the CTA-N site due to 10 minute average wind speeds of up to 100 km/h, and damage beyond the Serviceability Limit State must not occur due to 10 minute average wind speeds of up to 120 km/h when in the Safe State	Safe	Survival	Stable	Y	Mech&Cooling		Mech&Cooling	Analysis or Simulation	Partially Compliant		CTA-LLR-TN-0021_Camera Structural Analysis MST-CAM-TN-0455-CENBG_Front_Door_Design_Report	C-MST-CAM-NC-0055	Open	Camera structure fully compliant with possible necess reinforcement of the fixation of the large rear door Shutter should be protected by an on ground wind prot system (commun with FCAM)
CTA-200133	B-ENV-0735 Survival wind gust (North)	Damage beyond the Serviceability Limit State must not occur on the CTA-N site due to wind gusts (1s) of up to 200 km/h	Safe	Survival	Stable	Y	Mech&Cooling		Mech&Cooling	Analysis or Simulation	Partially Compliant		CTA-LLR-TN-0021_Camera Structural Analysis MST-CAM-TN-0455-CENBG_Front_Door_Design_Report		Open	Camera structure fully compliant with possible necess reinforcement of the fixation of the large rear door Shutter should be protected by an on ground wind prot system (commun with FCAM)
CTA-200134	B-ENV-0740 Survival wind speed (South)	Damage must not occur at the CTA-S site due to 10 minute average wind speeds of up to 80 km/h, and damage beyond the Serviceability Limit State must not occur due to 10 minute average wind speeds of up to 100 km/h when in the Safe State	Safe	Survival	Stable	Y	Mech&Cooling		Mech&Cooling	Analysis or Simulation	Partially Compliant		CTA-LLR-TN-0021_Camera Structural Analysis MST-CAM-TN-0455-CENBG_Front_Door_Design_Report		Open	Camera structure fully compliant with possible necess reinforcement of the fixation of the large rear door Shutter should be protected by an on ground wind prot system (commun with FCAM)
CTA-200135	B-ENV-0745 Survival wind gust (South)	Damage beyond the Serviceability Limit State must not occur on the CTA-S site due to wind gusts (1s) of up to 170 km/h	Safe	Survival	Stable	Y	Mech&Cooling		Mech&Cooling	Analysis or Simulation	Partially Compliant		CTA-LLR-TN-0021_Camera Structural Analysis MST-CAM-TN-0455-CENBG_Front_Door_Design_Report		Open	Camera structure fully compliant with possible necess reinforcement of the fixation of the large rear door Shutter should be protected by an on ground wind prot system (commun with FCAM)
CTA-200136	B-ENV-0810 Solar radiation level	Damage must not occur due to solar radiation of up to 1200 W/m^2 (averaged over 1 hour) at a maximum ambient temperature of 35°C when in the Safe state.	Safe	Survival	Stable	Y	Mech&Cooling		AIV	Analysis or Simulation	Compliant		CTA-LLR--SP-023_NCAM Mechanical System Declared Material List	C-MST-CAM-NC-0056	Closed	All camera parts & connectors have been chosen to be in UV resistant. Validated by design. Some pieces have be p replaced (cf maintenance plan)
CTA-200137	B-ENV-0820 UV resistance	All components exposed to direct solar radiation must be UV resistant.	All	All	Stable	Y	Mech&Cooling		AIV	Analysis or Simulation	Compliant		CTA-LLR--SP-023_NCAM Mechanical System Declared Material List		Closed	All camera parts & connectors have been chosen to be in UV resistant. Validated by design. Some pieces have be p replaced (cf maintenance plan)
CTA-200138	B-ENV-0915 Dust and sand	Damage must not occur due to an environment with up to 2.3 x 10^5 particles of ≥5µm size per m³ of air for 90% of the time at 2m above ground. Note: This limit corresponds to the definition of ISO-Class 9 of ISO14644-1 for particles of this size.	All	All	Stable	Y	Mech&Cooling				Compliant	AIV plan, §6 Waterproofness IP55 tests	MST-CAM-TN-0400-IRFU_NectarCAMTest stanchitz		Closed	Camera is sealed. Tested by watering at Sachay + strong Adlershof
CTA-200139	B-ENV-1010 Aggressive atmosphere (North)	Damage must not occur on the CTA-N site due to the following Aggressive Atmospheric Concentration ranges when in the Safe State: NO, NO 2 , SO 2 < 3ppb	All	All	Stable	Y	ALL				Compliant		CTA-LLR--SP-023_NCAM Mechanical System Declared Material List		Closed	
CTA-200140	B-ENV-1020 Aggressive atmosphere (South)	Damage must not occur on the CTA-S site due to the following Aggressive Atmospheric Concentration ranges when in the Safe State: NO, NO 2 , SO 2 < 4ppb	All	All	Stable	Y	ALL				Compliant		CTA-LLR--SP-023_NCAM Mechanical System Declared Material List		Closed	
CTA-200141	B-ENV-1110 Earthquake damage limitation (South)	Damage beyond the Damage Control Limit State must not occur at the CTA-S site due to the following ground accelerations: Peak horizontal ground acceleration up to 0.26g, peak vertical ground acceleration up to 0.3 g, with a 10% probability of exceeding these figures within 10 years (reference return period 95 years)	All	All	In Review	Y	ALL		AIV	Analysis + tests	Non Compliant		021-A-CTA-LLR-TN - NectarCAM Structural Analysis	C-MST-CAM-NC-0301 C-MST-CAM-NC-0302	Open	The telescope structure significantly amplifies the seismi accelerations at the level of the camera, with acceleration g. The results of the analysis show a possible weakne camera attachment tabs, even for Operation Base Earthqu This point will have to be confirmed with a loc Reinforcement of the camera attachment tabs should done.
CTA-200338	B-ENV-1115 Earthquake damage	No damage must not occur at the CTA-N site due to peak horizontal ground acceleration up to 0.05 g and peak vertical	All			Y	ALL		AIV	Analysis + tests	Compliant		021-A-CTA-LLR-TN - NectarCAM Structural	C-MST-CAM-NC-0301	Closed	

Environmental Requirements | Common Telescope | MST requirements | CommonOn-Site | Structure Interface | Readme | ValidationData | Rapp ...

DD011_MST-CAM-SP-0257_NCAM_Verification_Matrix.xlsx

NectarCAM compliance with CTA requirements as shown during the CDMR

Colonne1	ENV	TEL	MST	On Site	STRUCT	Total	%
Req number	**32**	**44**	**22**	**36**	**57**	**191**	
Compliant	26	39	19	32	54	170	**89%**
Partially Compliant	4	1	2	1	0	8	**4%**
Non Compliant	2	0	0	0	1	3	**2%**
To be Confirmed	0	4	1	3	2	10	**5%**
Total	**32**	**44**	**22**	**36**	**57**	**191**	**100%**

Requirement Verification: Status after CDMR

- NectarCAM Requirement Management plan written
  - To clarify NectarCAM Requirement management which appeared not clear enough during the CDMR
  - Available on SharePoint & distributed to CTAO. Includes latest verification methods advised
- Verification Matrix Updated
  - Missing content (compliance, status, verification method) filled
  - Verification methods modified to be in agreement with CTAO ones
  - Updated version available on SharePoint & distributed to CTAO
- Clean up of NectarCAM level C specifications summary file
- List of *design verification* tests that will be performed on the QM in preparation
  - List of remaining tests to be done on the QM to fully demonstrate the compliance of NectarCAM design with respect to CTA requirements (thermal, readout, mass, wind)
  - Different to the production camera validation tests

CTAO SE Workshop on Requirements and JAMA

- Intended for all CTA Products, with a special focus on the respective Systems Engineers and Requirements Managers as audience
- 3 afternoons on April 13-15th
- Topics
  - Requirements Specification template update
  - How the Requirements Specification relates to New JAMA.
  - The Requirements Specification and its position in the document tree.
  - The new ICD templates and their relation to existing Interface Management documents.
  - The Verification Plan. Verification of existing System (B-level) requirements by the Product Teams, presentation of a draft Verification Plan template
  - Requirements & Verification: More on the new approach presented at the last PC Meeting
  - The Glossary
  - The Norm Register
  - Configuration Control and Management.
  - Document Management and JAMA

Conclusion

- NectarCAM CDMR meeting hold on February 16 &17th
- High priority Recommendations are to be completed as soon as possible and prior to the hardware procurement
- Several actions on going:
  - Weekly MST TCG meetings to complete MST Structure-camera interfaces
  - Monthly CTAO MST SE meetings
  - Definition of external Interfaces with ACADA
  - Completeness of the design verification demonstration
  - Redaction of NectarCAM Req. Management plan, update of Verification Matrix

- Formalization of Verification plan & flow down process and associated actions will be clarified after the CTAO workshop on Requirements and JAMA
  - I am confident that the work done at the camera & WP levels will ease a lot further actions required by CTA (as copy paste of NectarCAM specifications in JAMA)
  - NectarCAM agrees that verification demonstration should be improved, but requested actions should clearly consider the level of development of the project

Questions ?