**DELIVERABLE NAME: CTA Level 1 trigger**

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NATURE OF THE DELIVERABLE: R**= Report, **X P**= Prototype, **D**= Demonstrator, **O**= Other   
**BENEFICIARY(IES) CONTRIBUTOR(S): ULEIC, ULIV, UOXF  
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DISSEMINATION LEVEL: X RE,  CO**  **PU** = Public N/A IN THE INFIERI CONTEXT **PP** = Restricted to other programme participants (including the Commission Services) N/A IN THE INFIERI CONTEXT **RE** = Restricted to a group specified by the consortium (including the Commission Services) **CO** = Confidential, only for members of the consortium (including the Commission Services)

**Abstract:**

The deliverable here is the trigger system for the Compact High Energy Camera (CHEC) designed for the dual-mirror Small Size Telescopes (SSTs) of the Cherenkov Telescope Array (CTA). CHEC has 2048 pixels of size 6 × 6 mm2, arranged in 32 modules with 8 × 8 pixels each. The signals from the pixels are first amplified and shaped, then passed to ASICs which form a module trigger by combining the signals from the pixels, as well as digitizing the data at a rate of 1 Gs/s. The required pre-amplifiers and shapers have been designed, constructed, tested and mounted behind 64-pixel multi-anode photomultipliers (MAPMs). The digitization and triggering circuitry, based around the TARGET 5 ASIC, has been designed, constructed and tested. These sensors and TARGET modules have been mounted in a prototype camera, CHEC-M. The TARGET modules pass trigger signals to a backplane, which combines the signals to form a camera trigger. If a valid trigger is generated, readout occurs through the camera’s data acquisition (DAQ) boards.

CHEC-M has been extensively tested and calibrated in the Laboratory and tested on one of the prototype SSTs, the Gamma-ray Cherenkov Telescope (GCT), on the Meudon site of the Paris Observatory. Despite the extremely difficult conditions on this site (the night sky background is orders of magnitude above that at the CTA southern site in Paranal, Chile, where the cameras will be deployed), CHEC-M was able to operate stably, record the Cherenkov signals generated by cosmic-ray induced air showers. This demonstrated the viability of the CHEC module and camera trigger systems, as well as that of the camera readout and control hardware and software, the DAQ and the design of the complete GCT. The trigger threshold achieved with CHEC-M is larger than desirable due to noise induced in the trigger section of the TARGET 5 chips by the sampling process.

A further camera, using silicon photomulitpliers (SiPMs) rather than MAPMs is under construction. This will use the same electronics chain as CHEC-M, with modifications of the front-end amplifiers and shapers resulting from the different SIPM signals. It will also use a new TARGET chipset, which has been designed to solve the trigger noise problems observed in CHEC-M. Laboratory tests indicate that trigger thresholds below one photoelectron are now achievable, easily satisfying CTA requirements. Modules incorporating these chips have been designed and constructed. An improved backplane has been built and tested. These subsystems will be incorporated in an SiPM-based prototype camera and tested on the GCT prototype in 2017. Tests on the second SST design, ASTRI, are also foreseen on the prototype at the Serra La Nave observatory on Mount Etna in Sicily.

**Talks**

**A. De Franco** and **G. Cotter** for the CTA Consortium, [Test bench for front end electronic of the GCT camera for the Cherenkov Telescope Array](http://iopscience.iop.org/article/10.1088/1748-0221/10/08/C08011), Journal of Instrumentation, Volume 11, February 2016, proceedings of INFIERI 2nd International Summer School on Intelligent Signal Processing for Frontier Research and Industry <http://dx.doi.org/10.1088/1748-0221/11/02/C02006>

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**A. De Franco**, **G. Cotter** for the GCT Collaboration, [Development of the GCT camera for the Cherenkov Telescope Array](https://indico.cern.ch/event/404880/session/0/contribution/42/attachments/1176991/1702366/GCT_INFIERI_PISA.pdf), 6th INFERI Workshop, Pisa, 2015

**A. De Franco** for the GCT collaboration, [The Backplane of the GCT Camera](http://infieri-network.eu/sites/default/files/CTA_Consortium_Liverpool_15_Backplane.pdf), CTA Consortium Meeting, Liverpool Sep 2015

**A. De Franco**, **G. Cotter** et al., [The first GCT camera for the Cherenkov Telescope Array](http://arxiv.org/abs/1509.01480), conference proceedings of the [34th International Cosmic Ray Conference, July 30 - August 6, 2015 The Hague, The Netherlands](http://icrc2015.nl/) (ICRC2015)

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**De Franco A.**, [Front End Electronics for the Cherenkov Telescope Array](http://infieri-network.eu/sites/default/files/users/user270/FEE%20for%20CTA%20-%20INFIERI%20Geneva%202015.pdf), 5th INFIERI workshop, Geneva, April 2015

**Dumas D. et al.** including  **Greenshaw** **T.** and  **Hinton J.**, SST dual-mirror telescopes for the Cherenkov Telescope Array. Proceedings of the SPIE, Volume 9145, id. 91452Z 12 pp. (2014). (SPIE Homepage) DOI: [10.1117/12.2055089](http://dx.doi.org/10.1117/12.2055089)

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**Doni M. ,Visser J.**[*Edge-on illumination photon-counting for medical imaging*](http://infieri-network.eu/sites/default/files/2014_summer_school_mdoni_poster_1.pdf), INFIERI 2nd International School on Intelligent Signal Processing for Frontier Research & Industry, 14-25 July 2014, Paris, France

**Schioppa E., Pellegrino A., Visser J.,**[*Timepix based lab course*](http://infieri-network.eu/sites/default/files/users/user270/Lab45_-_MPX_lab_intro.pdf), INFIERI 2nd International School on Intelligent Signal Processing for Frontier Research & Industry, 14-25 July 2014, Paris, France [also related to WP7]

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**De Franco A.,** [The Compact High Energy Camera for the Cherenkov Telescope Array](http://infieri-network.eu/sites/default/files/users/user270/The%20Compact%20High%20Energy%20Camera%20for%20CTA.pdf), UK National Astronomy Meeting, 23 - 26 June 2014, Portsmouth UK

**De Franco A.,**[CHEC Readout Software](http://infieri-network.eu/sites/default/files/Intelligent%20Front%20End%20for%20CTA%2C%20INFIERI%202nd%20workshop.pdf), 8th CTA-SST meeting, 3 - 5 June 2014, Amsterdam Netherlands

**Cotter G.,** [Introduction to CTA experiment](http://infieri-network.eu/sites/default/files/users/user270/CTA-intro-INFIERI-Madrid.pdf)**,**INFIERI Workshop, 20-22 January 2014, Universidad Carlos III de MADRID, Madrid

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**Greenshaw T.**, [The Small-Sized Telescopes of the CTA](http://infieri-network.eu/sites/default/files/users/user270/ViolentUniverse131101.pdf), Topical Research Meeting: The Violent Universe, 31/10/13-1/11/13 [also related to WP4]

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**Outreach related event**

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**Greenshaw T.**, « [In Our Time, Cosmic Rays](http://www.bbc.co.uk/programmes/b01sdnkg)», BBC Radio 4 discussion programme with Melvyn Bragg, 16 May 2014

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**De Franco A., G. Cotter,** Gamma ray sky with CTA, Public Talk for  [Stargazing Oxford,](http://www2.physics.ox.ac.uk/events/2014/01/11/stargazing-oxford-2014) 5 March 2014, Oxford UK

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**Greenshaw, T.,** Cosmic Rays, Daresbury Master Class, Daresbury Laboratory, Cheshire, UK.  26 and 27 March 2014

**Greenshaw T.**, The Small-Sized Telescopes of the CTA, Topical Research Meeting: The Violent Universe, 31/10/13-1/11/13

**Greenshaw T.**, The Non-Thermal Universe, Walsall Astronomical Society, 3/3/16

**Greenshaw T.**, The Non-Thermal Universe, Guildford Astronomical Society, 1/9/16