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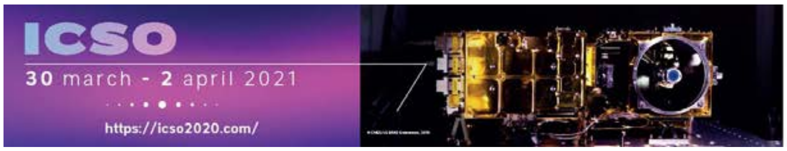

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CHIME's Hyperspectral Imaging Spectrometer design result from Phase A/B1

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ABSTRACT

CHIME, the Copernicus Hyperspectral Imaging Mission for the Environment, is one of the six High Priority Candidate Missions (HPCM) of the evolution in the Copernicus Space Component (CSC) foreseen in the mid-2020s that is proposed for further analysis. In this paper we summarize the results as retrieved by OHB (D) as part of the Phase A/B1. The contract was kicked off in 2018 and concluded in 2020 after finalisation of the Pre-development activities.

The proposed instrument is a hyperspectral imager instrument with reflective telescope and grating-based spectrometer. The selected orbit is in the range of 625 ± 30 km, LTDN 10:45 – 11:15 am with a repeat cycle of 20 to 25 days for a single satellite and 10-12.5 days revisit for 2 satellites. The payload of each satellite records at a Spatial Sampling Distance (SSD) of 30m the full spectral range from 400 to 2500nm at a Spectral Sampling interval < 10nm with Low Keystone/Smile.

On the front end a high performance TMA with wide-band coated optics collects the light from ground and feeds it to a highly linear almost distortion free spectrometer assembly attaining very good spectral stability. All units are integrated in an optical bench structure that offers excellent AIT access and provides a highly stable LOS. The electro-optical backend contains low-noise cold MCT detectors creating margin in the predicted NEDL performance. The instrument can be calibrated via on-board devices or using reference targets outside the spacecraft.

We present the functional decomposition and the physical instrument architecture: the optical design and opto-mechanical layout, the electro-optical imaging chain ant thermal control system.

Keywords: Remote Sensing, Hyperspectral, Spectrometers, Free-form Optics

1. INTRODUCTION

Evolution in the Copernicus Space Component (CSC) is foreseen in the mid-2020s to meet priority user needs not addressed by the existing infrastructure, and/or to reinforce services by monitoring capability in the thematic domains of CO2, polar, and agriculture/forestry. For this 6 High Priority Candidate Mission (HPCM) were proposed for further analysis. One of them, the Copernicus Hyperspectral Imaging Mission For the Environment **(**CHIME) is driven by the primary objectives i.e. agriculture, soils, food security and raw materials.

The Main Mission Objective of the Copernicus Hyperspectral Imaging Mission is: *"To provide routine hyperspectral observations through the Copernicus Programme in support of EU and related policies for the management of natural resources, assets and benefits. This unique visible-to-shortwave infra-red spectroscopy based observational capability will in particular support new and enhanced services for food security, agriculture and raw materials. This includes sustainable agricultural and biodiversity management, soil properties characterization, sustainable mining practices and environment preservation."*[1]

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Scheduled for the second half of the 2020s, CHIME will advance its two hyperspectral precursors, EnMAP [2] and PRISMA [3] by providing continuous hyperspectral mapping all land surfaces between -56° S latitude and +84° N latitude at around 10-12 days revisit in a constellation of two satellites. The in-orbit nominal lifetime in orbit is 7.5 years with propellant to allow an extended lifetime of 5 additional years.

The Phase A/B1 from 2018 to 2020 studied besides observation requirements, especially the related technology readiness, cost, risk, and schedule. Several predevelopment activities increased the Technological Readiness of various components.

Instrument Architecture

The CHIME instrument is built upon the concept of a pushbroom imaging spectrometer. The instrument provides ~130 km of swath at 30m GSD employing spatial swath-splitting: a single wide field Three Mirror Anastigmat (TMA) telescope with a folding mirror feeds three independent identical full wavelength range (400-2500nm) 'VISIR' grating spectrometer back ends in a staggered slit configuration with overlap. The de-magnifying optical design allows the telescope to operate at F#/5.5, while the spectrographs are built in a more compact arrangement at F#/3.3. The Offner-type spectrometers employ dual-blazed gratings delivering 10nm SSI. Chapter 2 discusses the telescope and spectrometer optics in more detail.

The instrument is built around a central torus-like hollow CFRP frame structure that provides the necessary opto-mechanical stiffness in a single element. The telescope mirrors and sub-structures mount directly to the central torus as does the AOCS equipment. At the focal plane of the telescope, the three identical spectrometer units are mounted on a common spectrometer support structure that connects to the central optical frame torus from below to keep the CoG close to the platform. The structure of the instrument is further discussed in Chapter 3.

All units, except the three MCT detectors, work at ambient temperature. The three cold (~170K) detection back ends are built around the Teledyne CHROMA-D MCT 3k detector as a baseline. It features 3072 pixel in spectral and 512pixel in spatial direction. The pixel are binned 2x2 to decrease the NEDL. Both the slit limited spatial sampling interval (SSI) of 8.4nm and the 30m SSD are Nyquist sampled before binning and can be transferred unbinned for instrument checks or calibration.

The Thermal control System (TCS) is based on a robust passive cooling chain with margin using a single two-stage radiator with CPC reflector to cold space.

The instrument is spectro-radiometrically calibrated by using reference targets, for solar absolute radiometric calibration, and spectral calibration, and vicarious calibration via proxy targets, such as ground, moon, and atmosphere).

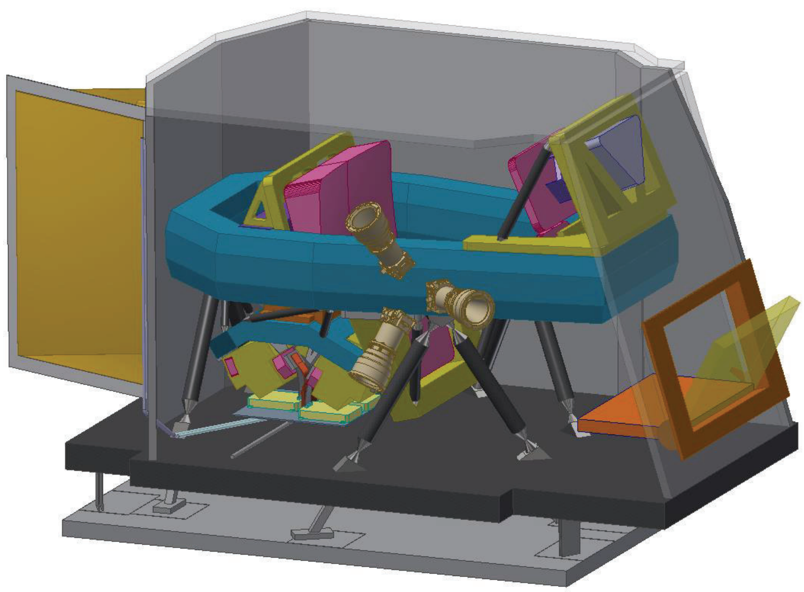

Figure 1. CHIME Instrument Architecture Concept Overview

The figure below shows the conceptual layout of the instrument. It shows the main entities and building blocks of the instrument in their relative/approximate spatial and in their functional arrangement.

The platform is located at the bottom, the instrument towards the top. The instrument is mounted on the top panel of the platform, with a main mount that interfaces to the optical bench unit and auxiliary mounts that interface to the instrument support panel (ISP). They are independent, so that optical bench stiffness and ISP/Platform stiffness are decoupled.

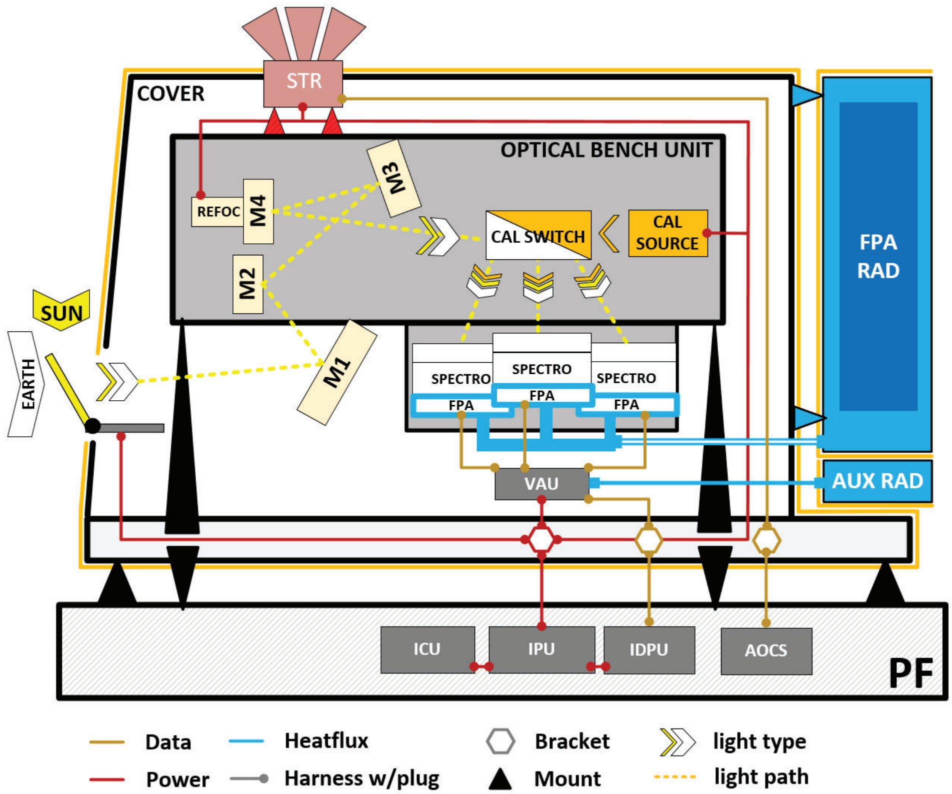

Figure 2. Instrument layout diagram with the two light paths for earth observation (white arrows) and calibration (sun calibration yellow, spectral calibration orange).

The instrument is closed with a cover structure equipment (black line around the main parts in the sketch) and is covered in multi-layer insulation (yellow line). The radiators of the thermal control system are mounted on the cover on the outside of the instrument. Attitude control sensors like the Star trackers, are also fully or partly on the outside.

All other components are inside the instrument cavity provided by the cover structure. The instrument features a central optical bench, the Optical Bench Unit (OBU, grey rectangle on the top of the cavity) to which all other systems interface. The front end of the optical system, the telescope with its mirrors (TELE, M1-M4) and their mounts are on the left, a part of the calibration equipment on the right. The light path (dotted line) is folded to make the instrument more compact. The Spectrometer Structure, the grey rectangle hanging on the bottom of the OBU is a structure that holds the three spectrometers, the backends of the optical system. The three identical spectrometers are in a staggered and offset arrangement. They consist of a slit, a spectrometer unit and a detector focal plane assembly (FPA). The electrical connections from the three digital read-out detectors are routed to three identical video acquisition units (VAU). Cooling for the detectors is realized by three thermal straps that interface to a common thermal link and redundant cryogenic heat pipes that connect to a focal plane radiator unit (FPA RAD) facing cold space. Cooling to the VAUs is provided by an instrument radiator unit (AUX RAD via a standard heat pipe).

In this arrangement light enters the instrument from the left through an absolute radiometric calibration mechanism that can select between sun (calibration) and earth view (normal remote sensing operation). It then is picked up by M1 of the telescope. A unit located after M4, the ICSU, switches between light coming from the telescope, spectral calibration light (provided by a spectral calibration light source), and a dark position for dark calibration. The spectrometers and their slits pick up the light from the telescope focal plane and disperse it onto the detectors where light gets converted into electrical signals.
All harness that is routed towards the Platform and the units therein (the power unit, data handling unit, control unit, and the AOCS system) has a break at a bracket at the ISP that allow easy separation of the instrument and the platform.

2. OPTICS

2.1 General Architecture

The CHIME optical system comprises a single telescope feeding three functionally identical spectrograph units. Telescope and spectrographs are design as independent units and assembled at the slit interface. The telescope images the swath onto the three slits in the telescope focal plane, each slit being integral to a spectrograph unit – i.e. the slits pick-off the sub-swaths from the larger focal plane of the telescope. Each spectrograph creates the spectrum of the swath in 30 m square ground samples over the full spectral range of 400 nm to 2500 nm in a single grating order. The three spectrometers are arranged such that the individual slits have a nominal 30 pixel spatial overlap. To achieve this, the slits are put in a staggered configuration with the two outer slits in a common line and the middle slit being offset. The offset translates to ~1s temporal or ~7 km spatial offset on ground

The two units, telescope and spectrographs are arranged in a folded fashion as shown in the figure below. The light enters from the left and passes the TMA. A fold mirror after telescope mirror 3 (TM3) reflects the light through the gap between TM1 and TM3. The three spectrometers are located behind TM1 and below TM3. The light from the center slit passes the slit and enters the center spectrometer directly. The left and right slit are offset, shown at the bottom of figure3, and a small fold mirror after each of the outer slits folds the optical paths over to the left and right spectrometer. In this arrangement, the focal planes meet "back to back" creating a focal plane area for a common temperature control system for the three detectors.

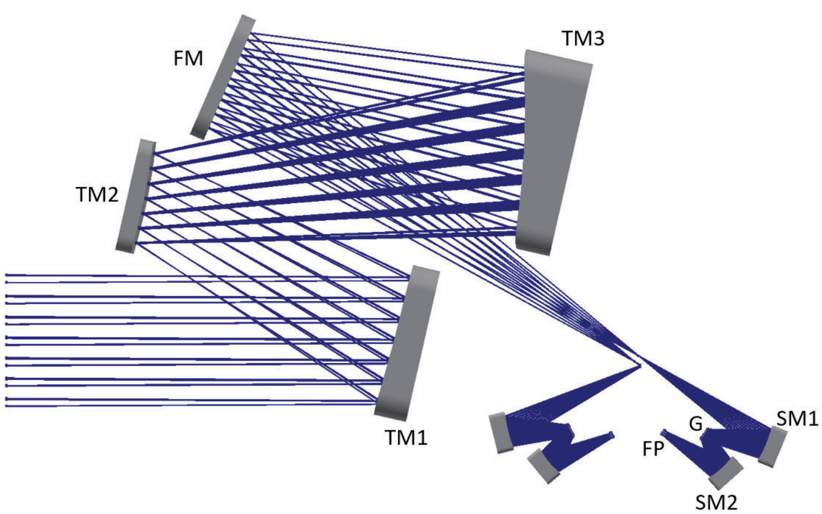

Figure 3. Instrument optical path layout.

The telescope and spectrograph are designed as independent units. The three spectrograph/telescope combinations must be considered to be independent systems, though the two outer systems are nominally identical. Each spectrograph contains the stop as an aperture in close proximity to the grating. That aperture determines the stop and diffraction contribution to MTF of the spectrograph/telescope system.

2.2 Telescope Optics

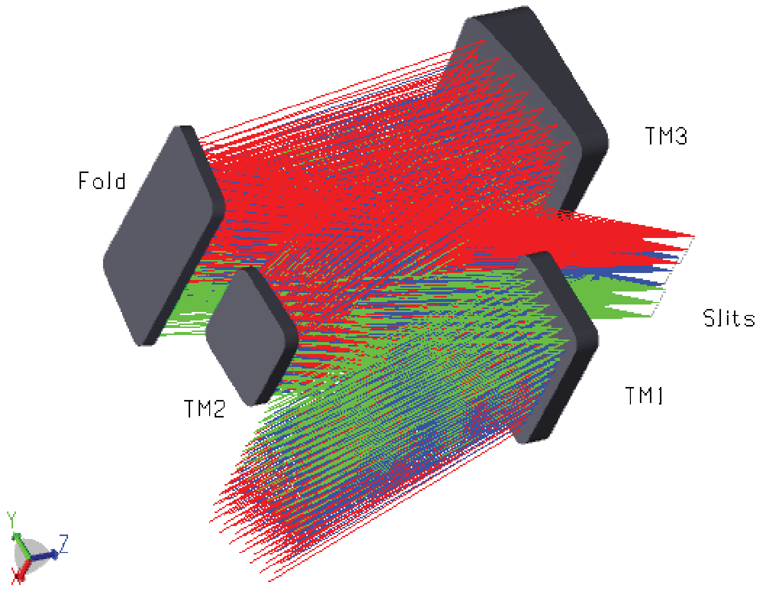

Figure 4. The telescope optics: a TMA of Wetheral-Womble type with powered mirrors TM1, TM2 and TM3, and a fold mirror at which focus correction can be applied during flight.

The telescope is a semi-classical, axis-symmetric, three mirror anastigmat (TMA) with three aparaboloidal mirrors and a fold mirror between the third powered mirror and slit plane. The clear apertures of each of the three powered mirrors (TM1, TM2 and TM3) are off axis, but the mirror surfaces are rotationally symmetric and co-axial with the telescope. It images an off-axis field into the slit plane and, because the spectrographs require slit-space telecentric feed, is designed for image-space telecentricity over full the field of view. The telescope is designed to be faster than is strictly necessary to feed the spectrographs because that excess speed relaxes the spectrograph-to-telescope alignment tolerances, and the system stop for each of the three telescope/spectrograph pairs is located at the grating in the spectrograph.

The fold performs two functions: (a) it places the slit planes and the three spectrographs under the telescope and (b) enables the use of a refocus mechanism that can be used to compensate for change in system focal length due to moisture release from the CFRP structure in the immediate aftermath of launch. Except possibly to compensate for long-term effects, after moisture release, focus will not be required because the telescope's focal length will be stable and the minimum orbit height is much greater than the telescope's hyper-focal distance at all wavelengths.

Table 1.Telescope parameters

	Design value	Comment
Focal length (mm)	1322	
Plate scale	155.9 arc sec. / mm	Paraxial
Semi-field	5.9° total, 1.9° per slit	Paraxial
Swathe	45,7 km per slit; Overlap 2 x 0.9 km	
Aperture (entrance)	Nominally 252 mm square with radius corners. (approx. 62580 mm^2)	Determined by the pre-image at the entrance to the telescope of the stop in the spectrographs

Spot size: The telescope design produces an RMS spot radius of between 3 µm and 4 µm in the center slit, and between 3 µm and 7 µm in the outer slits. This gives a telescope that is (by design) diffraction limited at or above 895 nm over most of the field. The spot radii compare with a slit width of 60 µm.

Wavefront error: The basic requirement is to produce a sufficiently low RMS WFE across the slit plane, that the secondary field that is the image of the swath at each of the three slits, is a source giving specification compliant ISRF and ACT MTF at the spectrograph detector planes. Telescope RMS WFE current design worst case is 80.4 nm for the central slit, and 284 nm outer slits. This will be re-balanced in favor of the outer slits later.

Figure 5. Wavefront error map: Center slit (top) with range 80.4 nm to 134 nm. Outer slits (lower) with WFE range 45 nm to 284 nm. In the outer slits, the WFE is highest at the innermost ends of the slits (light colour); in the centre slit the WFE is highest in the centre of the slit.

MTF: Along track the system's MTF is independent of the telescope's MTF; across track, the telescopes MTF influences the system MTF via the telescope's sagittal geometric MTF which, to an acceptable level of approximation for preliminary assessment multiplies the spectrograph's diffraction sagittal MTF. Apart from MTF or its corollaries, the optical performance of the telescope does not determine the system level optical performance.
The nominal design performance for the telescope in combination with the outer spectrograph is illustrated by the along- and across-track MTF in the figures below. Note that in this simulation the MTF results from the total system WFE. The MTF that results is higher than that predicted by combination of the telescope's geometric MTF and the spectrograph's diffraction MTF.

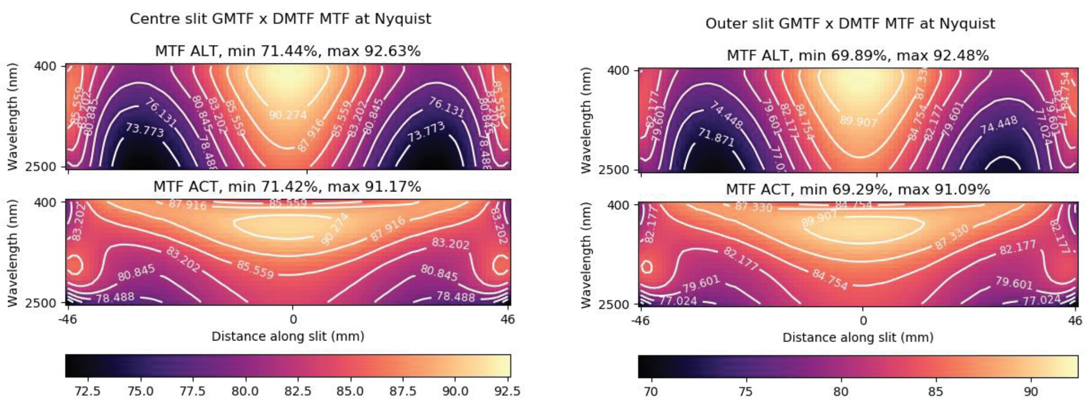

Figure 6. Tangential (ALT) and sagittal (ACT) MTF at the detector's Nyquist frequency of 13.88 cycles per millimeter, over the full detector from 400 nm to 2500 nm for the combined telescope and spectrograph for (left) the centre spectrograph unit, and (right) the outer spectrograph (where performance is lowest) for the current optical design. The asymmetry introduced by the telescope is evident in the right-hand figure.

Preliminary tolerance analysis indicates that, with the structural model refinement introduced to the mechanical model since this analysis was performed, the telescope will be sufficiently insensitive to the dominant influences on optical performance (component manufacture, alignment, gravity release and CME) that it can be assembled using existing procedures and will perform to optical specification when flown.

2.3 Spectrometer Optics

The CHIME system architecture relies on a set of three compact broadband Spectrograph Units (SU) forming the spectrometer equipment (SE). Each SU covers the complete 400-2500 nm VISIR spectral range, and have their slits arranged in a staggered configuration in the TMA focal plane. The SU consists of an all reflective optical instrument building upon AMOS' heritage in the domain of compact, high performance, long slit spectrographs. Its customized Offner-Chrisp layout includes a key enabler feature: the de-magnification function. The original benefit behind a built-in slit de-magnification lies in the relaxation of the optical constraints put on the front-end optics, including the slit itself, through the reduction of the object space F# by an identical factor, without degrading the instrument spatial resolution. Additionally, in the specific frame of the CHIME SE design, the tailored slit de-magnification creates extra mechanical clearance between the focal plane areas of individual units through the concomitant increase of the slit length, and the associated reduction of the back-focal distance, a decisive factor for the SE staggered slit configuration.

The SU optical design is optimized to satisfy the demanding image quality and focal plane distortion requirements (smile and keystone) over the wide focal plane area through the use of two freeform mirrors. The better aberration control provided by freeform optics, over a field that is large for such compact optics, enables the design of a simple, compact, high performance SU covering the full spectral range with a single focal plane sensor. Each unit throughput is ensured by employing a squared aperture over a broadband convex diffraction grating. The SU throughput over the complete spectral range is attained by relying on an advanced grating blazing technology. The availability of a broadband diffractive component enables the design of a SU with a single Focal Plane (FP) covering the full spectral range, alleviating the use of complex optical elements and cumbersome FP co-alignment strategies. The proposed all reflective solution is fully compatible with an all-aluminum alloy build, providing a good athermal system. This solution takes advantage of an extensive manufacturing heritage at AMOS, using Single Point Diamond Turning (SPDT) technology (e.g. Sentinel 5p's Tropomi, Proba V, Chandrayaan II).

Table 2. CHIME SU nominal design performances

	Design value	Comment
MTF	0.8	Over full focal plane , binned pixel
Keystone	< 0.07 pixel	Binned pixel
Smile	< 0.07 pixel	Binned pixel
WFE (RMS)	0.06λ @ 400 nm – 0.43λ @ 2500 nm	
Spectral range	400 – 2500 nm	Over single focal plane
SSI	8.4 nm / pixel	Binned pixel
F# (equivalent)	3	Rounded square aperture

The SU design, based on the experience gained with the ELOIS [5] spectrometer, achieves the tight CHIME SE specifications in terms of both geometrical and radiometric performances. Monte Carlo analysis reveals the performances are consistent with usual tolerances.

The CHIME SU optical design is presented in the figure below. It allows the high fidelity dispersion of the 90 mm long input slit over each of the 250 contiguous spectral bands composing the focal plane. This efficient ultra-compact design builds upon AMOS' experience taking advantage of three key elements:

- A convex, spherical, diffraction grating (GR) ensuring a high diffraction efficiency over the full spectral range: The high throughput over the complete VISIR range is achieved by optimizing a dual-blaze groove profile. In addition, this complex profile also significantly reduces the typical polarization sensitivity of such components.

- Two concave freeform mirrors (SM1, and SM2) allow the target optical performances to be reached over the VNIR+SWIR spectral range, and full input slit length.

- Built in slit de-magnification ensuring the extreme compactness of individual spectrograph unit – a key enabler of the SE system

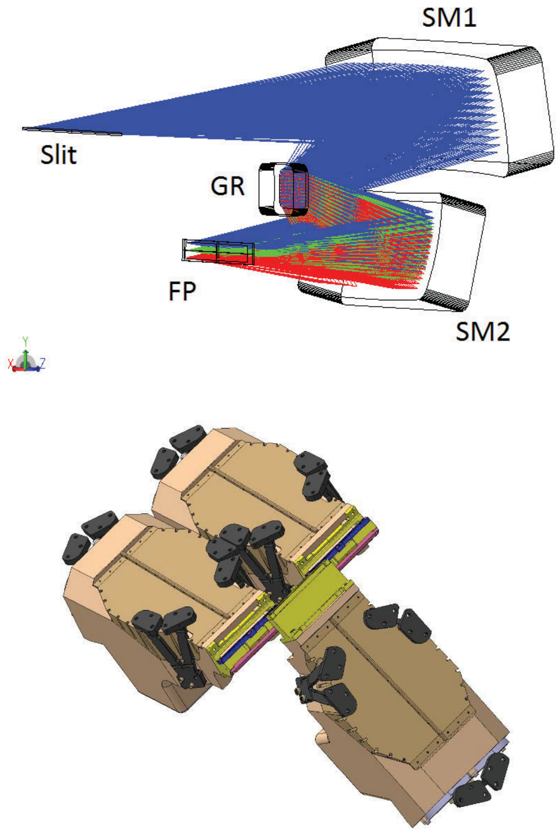

Figure 7. Top: Each CHIME SU Optical design comprises two freeform mirrors (SM1, and SM2) and a broadband, spherical, diffraction grating (GR). Bottom: The staggered arrangement of the three SUs defining the SE.

The design line spread function of the Spectrometer is shown in the figure below.

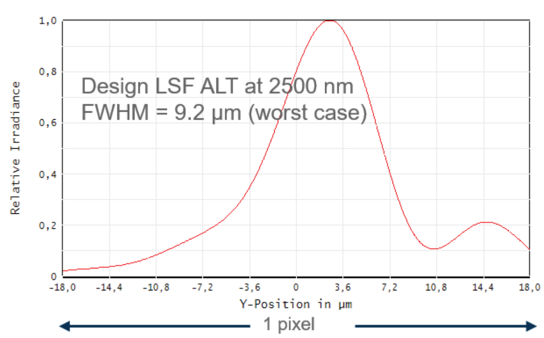

Figure 8. Line spread function of the spectrometer along track at 2500nm.

3. OPTICAL BENCH AND INSTRUMENT STRUCTURE

The overall instrument structural architecture was derived to meet a few key parameters: First, the structure needs to ensure structural integrity to survive any environmental loads at minimum mass. To achieve that, a frequency decoupling approach was applied between the Platform, the instrument and all subsequent subsystems. Furthermore, thermo-elastic distortions and effects of IF tolerances on the optical instrument need to be minimized.
All elements of the optical and electro-optical imaging chain are held by a single stiffness-providing element, a central monolithic CFRP torus (made from monolithic CFRP composite with no honeycomb core), creating an ultra-stable stiffness architecture for the instrument's structure. Having one central stiffness providing element increases the predictability of the entire stiffness architecture and thus greatly improves the robustness of the instrument design. Furthermore, it provides advantageous thermo-elastic stability and maximum access for AIT activities through an open frame concept. The rough dimensions of the instrument outline are 2.8m by 1.2m by 1.4m at around 450kg.
The design concept depicted in Figure 9 shows a robust margin on the demanding stability requirements of this mission in Line-of-Sight stability, pointing accuracy and spatial and spectral co-registration of the recorded data.

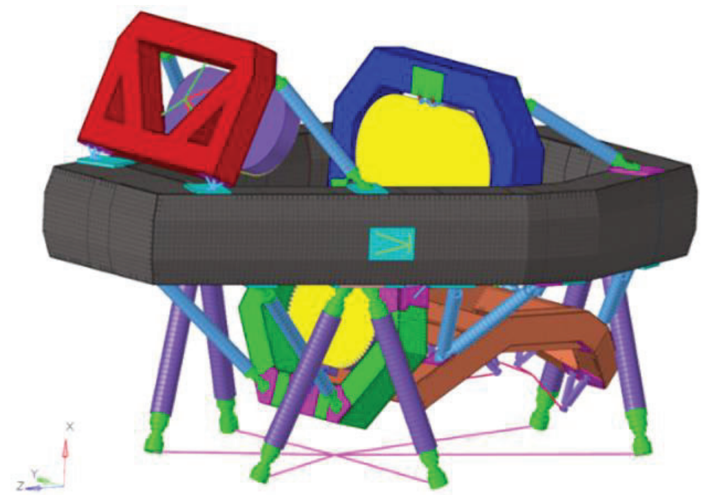

Figure 9. Structural architecture showing the central optical bench torus (black) to which the other units attach

The CFRP main torus carries the telescope unit consisting of the four Zerodur mirrors that connecting them isostatically to the CFRP main frame via dedicated CFRP sub-frames or directly via kinematic mounts. The three spectrometers mount to the torus towards the rear and lower side of the torus via an isostatically connected spectrometer unit support structure. As can be seen from Figure 9, an overall stiffness architecture with multiple layers of connected sub-structures has been derived. The main advantages of this hierarchical stiffness architecture comprised of a main CFRP frame and multiple local CFRP sub-frames are the following:

- Three levels of opto-mechanical decoupling is achieved between the ISP and the optical elements.
- Idealized 1 DOF struts (with point connections) are used to connect any structural sub-frame with the main frame.
- An almost ideal iso-static mounting concept is achieved between the sub-frame and the main torus.
- Due to the opto-mechanical decoupling features, no back-coupling of the main frame and the sub-frames and thus the optical elements exists.
- A fully deterministic structural architecture is created which can numerically be predicted and characterized in an easy manner.
- A highly-modular structural concept with constant stiffness during the assembly and integration process is obtained. This means the stiffness of the overall structure does not change as elements/subsystems are added or removed from the assembly.

Considering these advantages, a modular structural architecture which high flexibility during the design, manufacturing and assembly process has been proposed. It is expected that the modularity and clear separation of the individual structural levels provides long lasting advantages in terms of risk mitigation, cost reduction and schedule.

Concerning the singular load-introduction zones created by these strut-based structural connections, a large amount of heritage and expertise from former projects can be applied such as the Sentinel-4 UVN instrument structure.

To achieve maximum opto-mechanical performance at minimum mass and volume, topology optimization is employed for deriving the CHIME instrument structural concept. The design optimization process flow for the spectrometer mounting structure (SMS) is shown in Figure 10. The aim of this design optimization problem is to find an optimized mechanical structure connecting the three individual spectrometer units to the main CFRP frame while not obstructing the optical path. The starting point of the design process is the definition of the design domain while explicitly excluding certain non-design domains (i.e., connections to the spectrometers and IF to the main CFRP frame). Next, the topology optimization problem is formulated as a mass minimization problem subject to displacement constraints on the individual spectrometer units. The numerical optimization problem is solved via the density method under a gravity-release load-case acting upon the entire SMS. The converged density field is then thresholded and a raw iso-surface is extracted. Using this rough geometrical outline, smoothing operations are applied to obtain a refined optimized geometry. Due to manufacturing limitations and the goal to manufacture the final SMS via CFRP struts connected by metallic end fittings, further design abstractions needed to be performed. The final truss design is then remodeled via finite elements (FE) and analyzed to verify the final performance of the SMS.

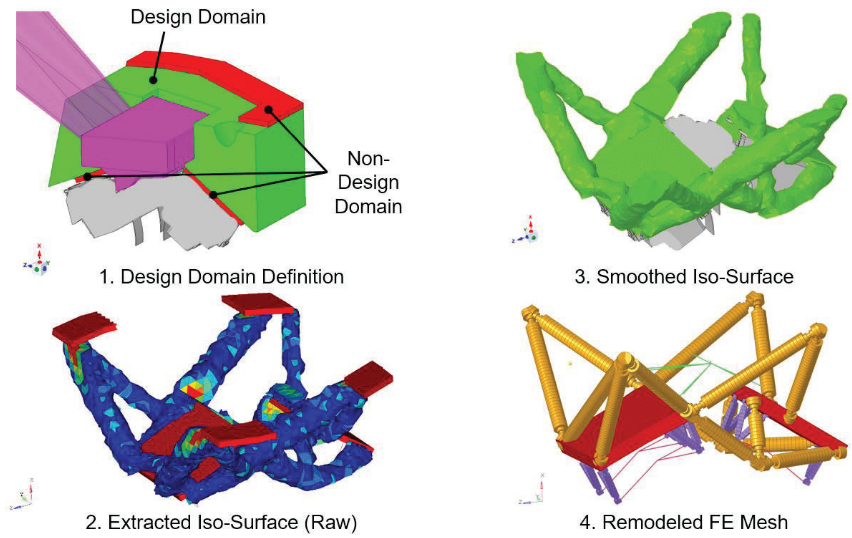

Figure 10. Topology Optimization Process flow from the design space definition to the remodeled FE model

Using topology optimization for systematic design, a non-intuitive high-performance opto-mechanical architecture was derived for the CHIME instrument. While not all constraints (e.g. material anisotropies or manufacturing limitations) were considered, a first design concept could be obtained very efficiently. Applying some final design modifications, the individually optimized sub-structures could very well be integrated into the overall stiffness architecture (Figure 9).

4. DETECTOR AND FOCAL PLANE

The FPS is composed by two different units the FPA (Focal Plane Assembly) and the VAU (Video Acquisition Unit). The FPA is composed by the following elements:

- The Detector Unit (DU) which is a CHROMA-D with 3072 x 512 pixel format encapsulated in a package that include the Order Sorter Filter (OSF) and the flex ribbon cable.
- FPA supporting structure that has the function of keep stable the detector position, thermally insulate the detector from the hot interface and provide an adjustable interface to align the detector sensitive elements with respect to the spectrometer.
- The thermal strap is directly interfaced with the detector package and is conductively linked to the heat-pipe thermal interface.

- The cold shield that is partially thermally insulated from the detector and has the function of reducing the thermal background that reach the detector

The FPA and VAU has different mechanical and thermal environment and are connected through the flex cable. The three FPA have an identical design with the only slight difference in the thermal strap length and interface with the HP. The three VAUs are identical and interchangeable

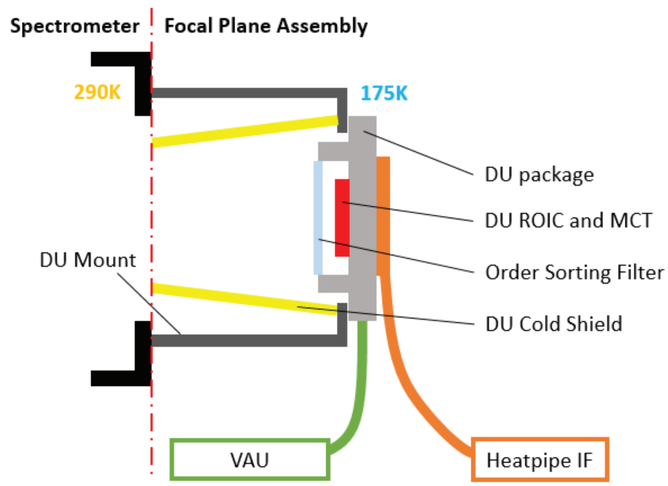

Figure 11. Detector Focal Plane Assembly

The selected detector for CHIME belongs to the CHROMA-D family with an array format of 3072 x 512 pixels. DU is composed by HgCdTe retina (0.4 µm-2.5 µm spectral band) hybridized to a ROIC. DU features on chip ADC (14 bit resolution) and 6 CML (up to 1.6Gbps) output ports for pixel array readout.
On the DU package an Order Sorter Filter (OSF) is mounted with the objective to suppress high diffracted order generated by the grating. The OSF proposed design is based on a staircase approach: different long pass filters are deposited one on top the other with Ion Assisted Deposition technique. The staircase approach allows to limit the coating thickness and minimize the “undefined” transition zone at the boundary from one filter to the other.

5. THERMAL CONTROL

The three Teledyne CHROMA-D detectors operate at ~175K to ensure the full performance over the full spectral range with cold-biased temperature control. The necessary cold sink is provided by a passive cryogenic radiator concept. It has been chosen over a mechanical cryo cooler for reliability, simplicity and absence of microvibration. Since CHIME operates in a low earth sun-synchronous orbit and maps the surface continuously, there exists a fixed cold-space-facing side on the payload at any time. Thus a cold radiator facing cold space at all times can be mounted on the instrument.

There exists a highly efficient heat flow path from the detector to the cryogenic radiator. High performance thermal straps are mounted directly to the sensor chip assembly base that holds the detector. Pyrolytic graphite straps couple the Focal Plane System (FPS) to the heatpipe, while decoupling the interface mechanically. The heatpipe then transports the heat dissipated by the three FPS directly to the cryogenic radiator, where it is rejected to space. All mounting interfaces between designed to have optimal heat transfer capability by using low roughness surfaces and/or thermal interfillers, as well as maximizing interface areas.

The radiator is a two stage design. The cold stage is used to cool the detectors, rejecting detector dissipation and parasitic heat fluxes on the detector cooling chain to deep space. All direct external fluxes onto the radiative surfaces of the cold and the warm stage are avoided by appropriate orientation and housing of the radiator. The radiator is located on the zenith side of the instrument with an angle towards Earth's limb that prevents any direct Earth or albedo flux. Direct solar flux is blocked by a sunshield, housing the radiative plates. Indirect Earth and albedo fluxes through reflections from the sunshield onto the radiative plates are minimized by an appropriate sunshield shape and coating of the reflector. The shape of the reflector also ensures better coupling of the cold stage surface to cold space. To reduce parasitic thermal inputs from the spacecraft, the radiator is a two stage design. Each stage is thermally decoupled from each other by MLI for radiative aspects and by low conductivity blades for conductive aspects.

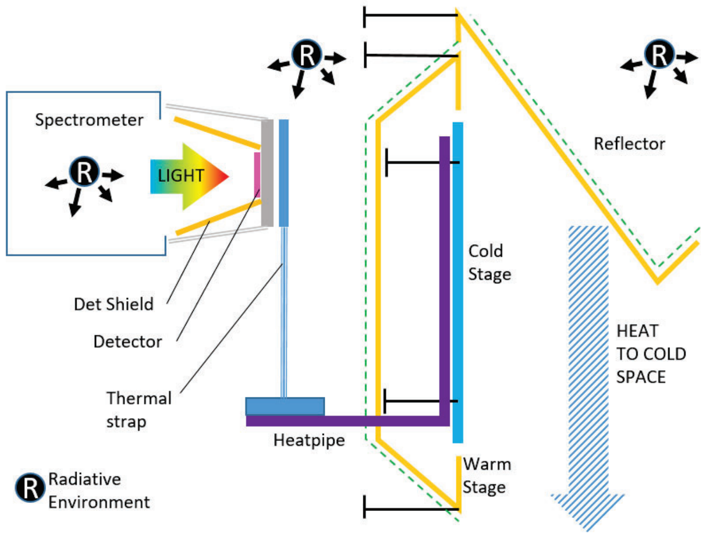

Figure 12. Thermal cooling chain for the detector

The simulated detector temperature from the thermal model over one orbit is shown figure 13. The presented stability is already achieved without any temperatures control at the Spectrometer Unit. Only the Instrument Support panel is actively temperature controlled. There is a total gradient of about 12°C from the radiator to the detector

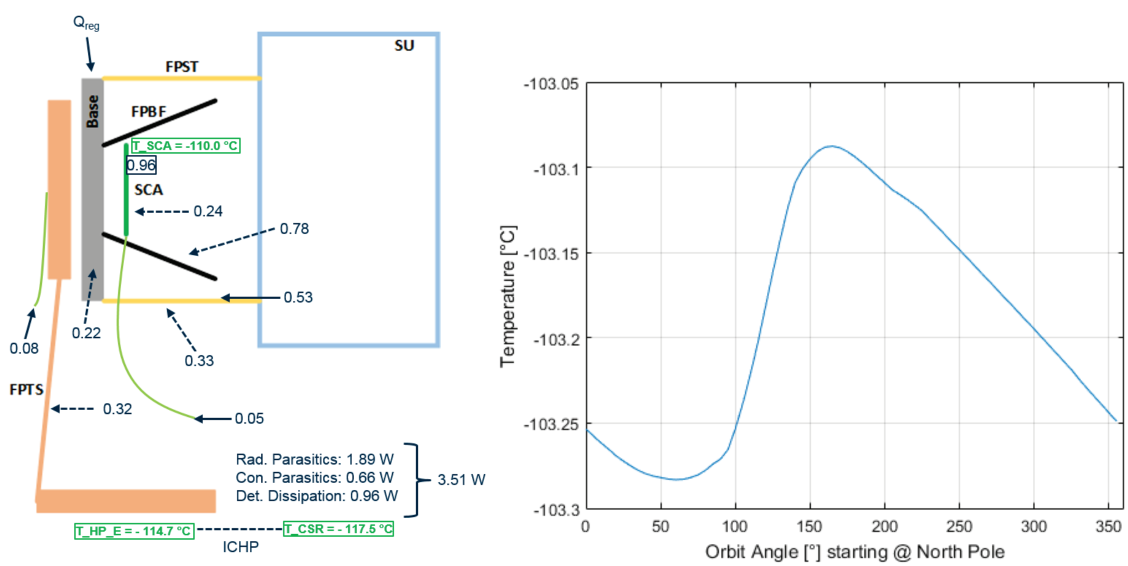

Figure 13. Heat flux and parasitic contributors [numbers in Watts] at the Detector (left) and detector temperature variation over one orbit (right)

6. PREDEVELOPMENTS & PARTNERS

The CHIME A/B1 phase described in this paper has been carried out by a consortium of Companies from Europe and the US under the lead of OHB –System AG, Germany. The table below lists the respective Partners and their contributions. Through the various Pre-Development activities the Technological Readiness could be increased.

Table 3. CHIME A/B1 Predevelopment Activities and Partners

Predevelopment / Aspect	Partner	Country
Mission Analysis & Planning	DEIMOS	Spain
Structure & Optical Bench	INVENT	Germany
Mirror Coating	CILAS	France
Spectrometer Subsystem	AMOS	Belgium
Slit	AMOS	Belgium
Grating	AMOS	Belgium
Grating	ZEISS	Germany
Order Sorting Filter	Optics Balzer	Germany
Detector	Teledyne-e2v	UK & USA
Data Compression Algorithm Definition	Politecnico di Torino	Italy
Data Compression Algorithm Implementation	TSD	Italy
L1c Processor	VITO	Belgium
Ground Calibration & Characterization	TNO	Netherlands

7. CONCLUSION / OUTLOOK

We have presented the payload/instrument focused results of the Phase A/B1 Study related to the High Priority Candidate Mission (HPCM) Copernicus Hyperspectral Imaging Mission For the Environment (CHIME). The general observation requirements, the complex trade-off related to available technology readiness, cost, risk, and schedule are described. An innovative instrument concept could be derived making use of robust technologies and good heritage throughout the chosen consortium. Through the various Pre-Development activities the Technological Readiness could be increased. The architecture and design concept presented has been adequately assessed in terms of technology and risk and properly verified throughout the Development & Design, Verification & Validation, and AIT flow.
Since the close out of the A/B1 phase, CHIME has entered the B2 phase. Design maturation and performances will be discussed in future papers/presentations.

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TNO (NL). Further, we acknowledge the steady contribution and effort of our colleagues at ESA-ESTEC (The Netherlands), ESA-ESOC (Germany), ESA-ESRIN (Italy) and especially the CHIME Mission Advisory Group (MAG) for actively supporting the missions.

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