ASTRO*tir*

A compact, lightweight & multi-purpose thermal infrared camera

Authors and Affiliation:

Dr. Simon Chelkowski Email: simon.chelkowski@jena-optronik.de, Mobile: +49 175 7416409,
Thomas Hennig, Thomas Schneider, Fabian Lami, Steffen Kirschstein,
Steffen Rienecker and Tina Voigt
Jena-Optronik GmbH, Otto-Eppenstein-Str.3, 07745 Jena, Germany

Abstract

We introduce ASTRO*tir*, our latest camera development, which extends Jena-Optronik's ASTRO© camera product line into the thermal infrared wavelength range. As ASTRO*tir* aims primarily at different applications on small and medium satellites, it will be a compact, lightweight and multi-purpose thermal infrared camera. Furthermore, we will expand our heritage of highly-reliable space products to support long lifetimes in geostationary and lower Earth's orbits with ASTRO*tir*. Its target mass budget of 300g is the driving requirement. To obtain a compliant design, certain design aspects need to be mastered. In this paper, we will provide details of related design trades. Additionally, we describe our conceptual design and report on the currently running bread boarding activities. We conclude by providing an overview of the ASTRO*tir* development, its schedule and milestones.

Introduction

- Jena-Optronik (JOP) has a strong heritage in the development of cameras for space-based applications
- JOP focus lies on cameras working in the visible & near-infrared range of the spectrum
  - Main application: Use as star trackers to support the satellites Guidance, Navigation & Control System. JOP is world market leader in providing star trackers to satellite prime manufacturers.
- Thermal and long wave infrared (LWIR) cameras are necessary for specific applications in the field of Space situational and space domain awareness (SSA & SDA).
- Extension of our successful ASTRO camera range into thermal infrared with ASTROtir (tir = thermal infrared) is aspired.
- SSA and SDA application cases are:
  - Observation of sat surrounding volume aiming to detect, track & identify incoming threats
  - formation flying (relative navigation),
  - approach and docking with a non-cooperative space object
  - detailed image generation of near satellite objects
- ASTROtir will be the first European off-the-shelf solution for an IR camera covering the application cases and mission scenarios.

Conceptual Design

Extract of ASTROtir key parameters

Requirement	Specified Value
Performance	
Thermal resolution	50 mK
MRTD	1 K
Size & Mass	
Dimensions	83 mm x 80 mm x 52 mm
Mass	570g wide FoV, 615g narrow FoV
Camera Resolution	VGA 640 x 480 pixels; up to 1280 x1024 pixels with design adaptations
Field of View	narrow: 20 deg / wide: 60 deg
Lifetime	6y / (10y)
Lifetime	<7W

Complete ASTROtir data sheet

Figure 4 ASTROtir product rendering. It has a quadratic layout with 80mm length in X- and Y-direction.

Figure 5 LWIR Camera Shutter configurations

Breadboarding Activities

The major motivation for the breadboard activity is to get to know the most essential hardware, its detector, early as well as to learn more about the behaviour of a thermal camera in general. The breadboard is available much earlier than any other hardware model used in the development program because it uses commercial proximity and readout electronics to drive the detector and produce image data. This allows focusing onto the specific detector behaviour under various environmental conditions and detector configurations states. A dedicated test program has been created and is currently being carried out, which allows an objective and comprehensive analysis of the detector behaviour in a reproducible manner and controlled environment.

Figure 7. Photo of the ASTROtir breadboard. Within the 3D-printed housing, one can see the commercial lens in the front as well as a shutter mechanism slightly behind and above the lens.

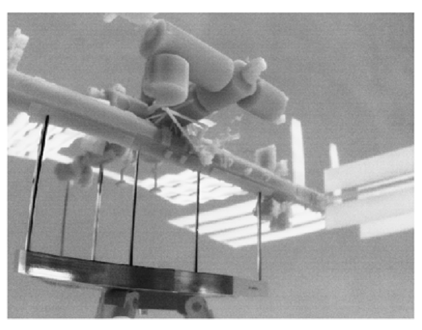

Figure 12. Thermal image of a 3D-printed model of the International Space Station.

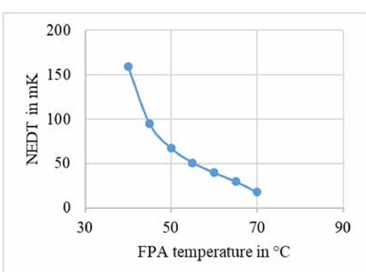

Figure 8. Noise equivalent differential temperature vs. detector temperature.

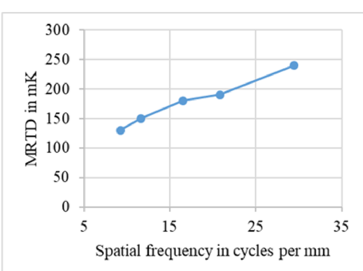

Figure 9. Minimum resolvable temperature difference vs. spatial frequency.

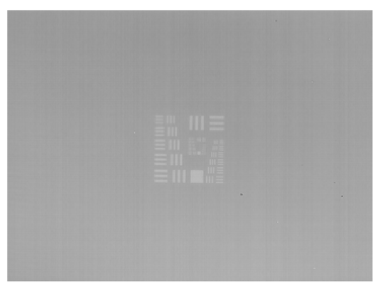

Figure 10. Image of USAF test pattern before NUC.

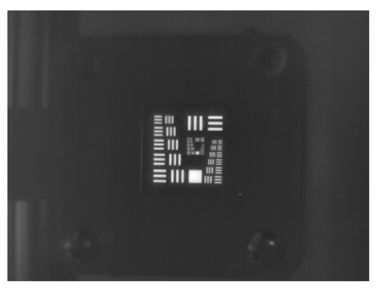

Figure 11. Image of USAF test pattern after NUC.

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Low Mass Challenge

- The initial conceptual design lay far away from the desired mass budget.
- Total mass reduced in a combined approach by adapting
  - the electronics architecture &
  - the optics architecture
- Electronics architecture:
  - Uses regulated DC input power
  - Uses a specific detector that provides all necessary on-chip analogue and digital functionalities to allow adjustable operation of the microbolometer array and pre-processing of the analogue output signals (e.g. gain selection, skimming).
  - Careful selection of EEE-parts for space applications - Higher integrated components required (dual amplifiers, dual channel ADCs, FPGA in a miniaturized packed together with SRAM, etc.)
  - Use of standardized protocols such as SpaceWire and RMAP (remote memory access protocol)
- Optics architecture:
  - Increased F# from 1 to 1.2
  - Reduced image resolution to 640x480px while using a detector with 1280x1024px

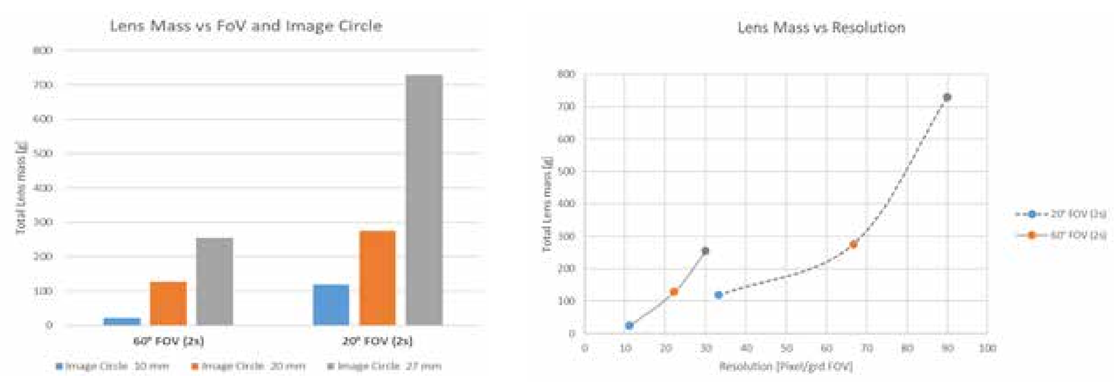
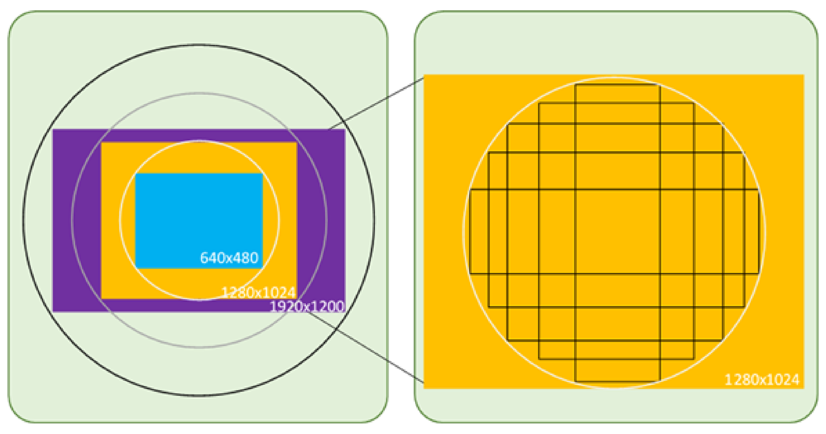


Figure 2 Total lens mass (Optics + Mounts) for different Field of views and different detector diagonals

Final mass budget after mastering the low mass challenge for the ASTROtir camera

Component	Estimates Masses Wide FOV 60°	Estimates Masses Narrow FOV 20°
unit	g	g
Mechanics Box	170	170
PCBs	120	120
Bits and pieces	20	20
Optics	30	60
Total mass	**340**	**370**

Table 1 Mass budget of ASTROtir



a) Schematics of different Detector vs. Imaging Size of the Optics. A small lens systems can work with larger detectors to obtain the same image information as with a small detector.

b) Ideas of a variable image formats. A small lens systems with a small Image size can be used with larger detectors to maximise information or to use variable image formats.

Figure 3 Schematics of image size and format w.r.t. detector diagonal

Development aspects and schedule

One major goal is to finish the ASTROtir development within 36 months.
The two main reasons for this are:

- Application cases for ASTROtir already exist; market demand increases; no European of the shelf solution of a compact, lightweight and high reliable thermal infrared camera is available. Additionally, an early market entry holds the opportunity for a good market population, leading to increased sales.
- Co-funding by GSTP Mittelstandsinitiative supports only 36 months activities separated in three 12 months long funding periods. Each period needs to be finished successfully before the funding for the next period is released.

Model Philosophy for the development:

- Camera Breadboard with desired detector and commercial optics and electronics in a 3D-printed housing with a breadboard shutter
- Engineering Model
- Engineering Qualification Model

Specialties of the individual Models:

- EM and EQM share the same design (goal), EM MAIV is starting after final design review
- EQM is used to perform qualification campaign and reach TRL8

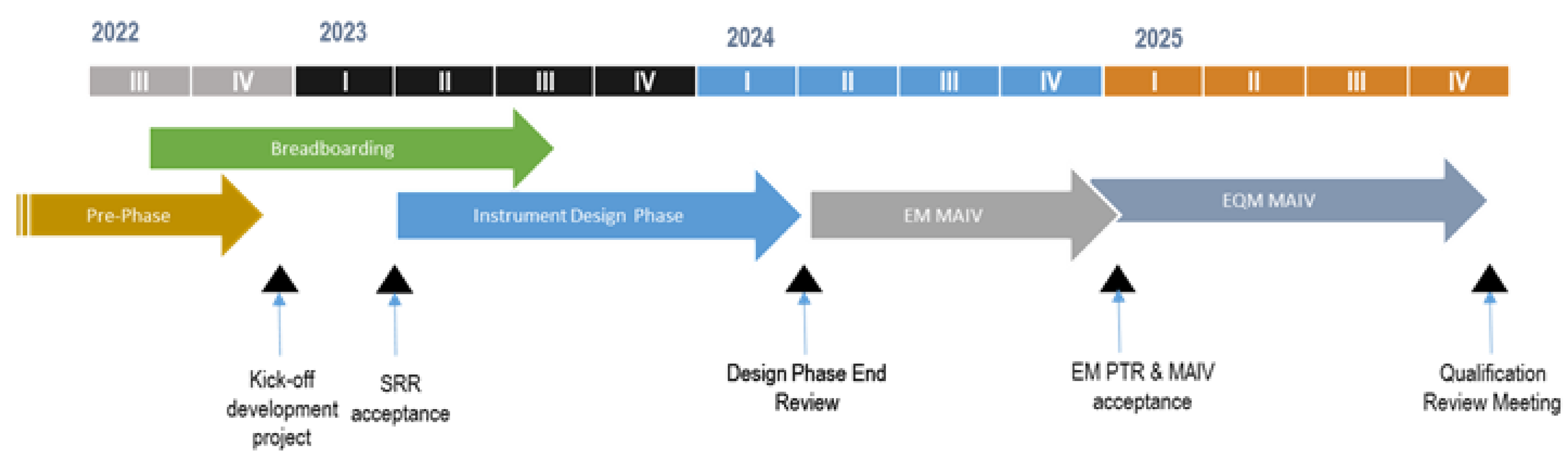


Figure 13: Development overview of the ASTROtir thermal infrared camera

Summary & Acknowledgement

In conclusion, we have presented a conceptual design, certain challenges we already mastered, our essential breadboarding activities and certain development aspects for our new thermal infrared camera ASTRO*tir*. It will extend Jena-Optronik's ASTRO© camera product line beyond the visible wavelength range. Furthermore, with ASTRO*tir* a unique European compact and ightweight thermal camera multi-purpose solution with long lifetimes in the harsh space environment will be available for the first time.

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space for success