HIRDES
Phase B1
Final Presentation
@DLR, Bonn
April 05, 2006

R. Graue; D. Kampf; Ch. Neumann
Contents

- Requirements
- Phase B1 Study Logic
- System Architecture
- Optical Performance
- Mechanical and Structural Design
- Thermal and Distortion Analyses
- Mechanisms Design
- In Orbit Calibration
- Electronics and Detectors
- Budgets
- Design, Development and Verification Plan
- Documentation
HIRDES Requirements
## HIRDES Instrument – Driving Requirements

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Baseline Requirements</th>
</tr>
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<tbody>
<tr>
<td><strong>Wavelength coverage</strong></td>
<td></td>
</tr>
<tr>
<td>▪ UV Spectrograph</td>
<td>174-310 nm</td>
</tr>
<tr>
<td>▪ VUV Spectrograph</td>
<td>102-176 nm</td>
</tr>
<tr>
<td><strong>Spectral Resolution</strong></td>
<td>&gt; 48000</td>
</tr>
<tr>
<td><strong>Minimum sensitivity</strong></td>
<td></td>
</tr>
<tr>
<td>▪ SNR= 10 in 10 h</td>
<td>16 mag (VUVES); 18 (UVES)</td>
</tr>
<tr>
<td>▪ SNR= 100 in 10 h</td>
<td>11 mag (VUVES); 13 (UVES)</td>
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<td><strong>Limit loads in all axes w/o SF</strong></td>
<td>15 g (tbc)</td>
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<tr>
<td><strong>Stiffness (first fundamental eigenfrequency)</strong></td>
<td>&gt; 40 Hz</td>
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<tr>
<td><strong>Envelope</strong></td>
<td>Protective Case</td>
</tr>
<tr>
<td><strong>Mass</strong></td>
<td>155 kg</td>
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<tr>
<td><strong>Power</strong></td>
<td>150 W</td>
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<tr>
<td><strong>Data Rate (downlink)</strong></td>
<td>1.6 Mbit/sec</td>
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Applicable Documents

AD1  User Requirements Document; 3.2006
AD2  Project WSOUV ; Phase A Preliminary Design(T170 M) ; 7.2005
Phase B1 Study Logic
Main Objectives of the HIRDES Phase B1 Study

- System Architecture and Design Conceptual Design
- Preliminary Engineering
  - Optical Performance of Spectrometers and IFGS
  - Structural Performance
  - Mechanical Configuration and Conceptual Design
  - Thermal Behaviour and Optical Stability
  - Electronics and Software Architecture
  - MCP / IFGS Detector Performance Analyses and Design
- External IF Engineering (Telescope, External Electronics Panels)
- Evaluation of Programmatic
  - Design, Development and Verification Plan
  - PA Approach
  - ROM Cost Estimations
Architectural Trades and Engineering - Overview

- Optical Analyses and Layout (Spot Diagrams, Ray Tracing)
- Thermal Analyses and Control (Passive, Active)
- Structural Analyses (Eigenmodes, Strength)
- Performance Analyses (Distortion Analyses, Tolerancing)
- Mechanical Design
- Mechanisms Concept
- MCP and IFGS Detector Design
- Instrument Electronics Design
- IF Engineering to S/C (Telescope, Electronics)
- Budgets (Mass, Power, Data)
- In Flight Calibration Concept -tbc
Study Logic Phase B1

KO

Architectural Design
ICD preparation

PM1

Preliminary Design and Engineering
DDV Plan and ROM Cost Estimation
Preliminary Documentation

FP (DLR)

Final Documentation
Phase B1 Team Configuration

IAAT
Scientific and Technical Management
MCP Detector Engineering Support

KT
Industrial Study Team
Optomechanics, Electronics

ISAS
Scientific Consultancy
Spectrometer Layout Expertise
# HIRDES Phase B1

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System Architecture
T 170 M Telescope
Baseline Configuration of HIRDES (VUVES and UVES)

- **Phase A**
  - UV and VUV Spectrometers Optomechanics (Optical Elements, Housing)
  - UV and VUV MCP Detectors (2 x 2) including Front End Electronics
  - ICU (Instrument Control and Data Processing)
  - HVPS and LVPS (High and Low Voltage Power Supply)
  - Thermal H/W
  - Mechanisms including Motor Control Electronics
    - Vacuum Shutter for MCP Detectors (UV, VUV)
    - Grey Filter Mechanism (UV, VUV)
    - Servo Mirror Mechanism (UV, VUV)
    - Echelle and Collimator Focus Mechanisms (UV, VUV)
- **Phase B1 (Additional Equipment)**
  - UV and VUV Internal Fine Guidance Sensor (IFGS) including Front End Electronics and Optics
Optical Performance
HIRDES Optical Layout incl. WSO/UV Telescope T170M

VUV Spectrometer

UV Spectrometer

**T170 M Telescope**
- Focal Length: 27 m
- Primary Mirror: dia. 1.7 m
UV spectrograph with echelle grating (40 lines/mm / 70deg.blaze) and prism (fused silica, 12 deg.)
UV Spectrograph - Focal Plane

Wavelength: 174-312 nm
Grating order: 253-149
UV Spectrograph - Focal Plane High Resolution (69000)

- Grating order 223
  - Wavelength: 206.7 nm
  - Spacing: 0.003 nm

- Grating order 222
  - Wavelength: 205.7 nm
  - Spacing: 0.003 nm

Spots at position 5 for demonstration only
UV Spectrograph - In Field Fine Guidance with Lens

In field reflected at prism front surface towards focus mirror via lens onto fine guidance detector
UV Spectrograph - In Field Fine Guidance Performance with Lens

- Spots at 550 nm with 10 µm pixel and 0.3 arcsec distance (instant illumination)
- Spots ranging at 600 and 630 nm with 10 µm pixel and 0.3 arcsec distance (instant illumination)
VUV Spectrograph

Spectral separation via echelle grating (65 lines/mm/71 deg. blaze) and cross disperser (on focus mirror, 625 lines/mm)
VUV Spectrograph - Focal Plane

Wavelength: 102-176 nm
Grating order: 282-165
VUV Spectrograph - In Field Fine Guidance

In field decoupled from 0th order reflection of grating via 2 mirrors onto fine guidance detector
VUV - In Field Fine Guidance - Performance

- Spots, 10 μm pixel
- 2 spots with 10μm pixel and 0.6 arcsec distance (instant illumination for demonstration only)
- Diffraction limitation due to 600nm wavelength and 160 m focal length (diffraction limited)
Mechanical and Structural Design
HIRDES Spectrometer Primary Structure - Baseline

- Modular Approach of Spectrometer Housing (Stand Alone Spectrometer Units)
- Monolithic CeSiC structure (conservative material, quasi isotropic behaviour)
- Light-weight approach
- Minimized Procurement costs
  - Fabrication technology available in Germany
  - Reduced Manufacturing tolerances
  - Standardized adjustment devices for each optical component
- Isostatic suspension for the HIRDES spectrometers to the Telescope I/F
- Isostatic suspension and thermal decoupling between detectors and Spectrometer Housing
Spectrometer Arrangement

UV Spectrometer

VUV Spectrometer
Critical Components Design

Mirrors and Gratings
- Quartz Glas with Invar flexural mounts
- WFE: $\lambda/20$ at $\lambda = 633$ nm
- Surface Roughness: < 1 nm
- Coatings:
  - UV: Al + SiO$_2$
  - VUV: Al + MgF$_2$
  - VIS: Al + SiO$_2$ (Option: Au)

Isostatic Mirror Suspension
(ORFEUS Heritage)
Critical Components Design

Isostatic Suspension made from CFRP
(PACS heritage)

Invar Suspension with SS flexural Blades
(ORFEUS Heritage)
Phase B1 Architecture

- **S/C- Bus**
  - cmd, control, data
  - Power

- **Electronics Subsystem**
  - ICU and MCE
  - cmd, control, data
  - Power Supply
    - LVPS, HVPS, Converter

- **Sensor Subsystem**
  - MCP UVES (Main/Red)
  - Vacuum Shutter Mechanism
  - Servo Mirror Mechanism
  - IFGS UVES

- **Optical Subsystem**
  - MCP VUVES (Main/Red)
  - Vacuum Shutter Mechanism
  - Servo Mirror Mechanism
  - IFGS VUVES

- **Telescope T170 M**
  - UVES
  - Grey Filter Mechanism
  - Spectrometer Optomechanics
  - Entrance Slit

  - VUVES
  - Grey Filter Mechanism
  - Spectrometer Optomechanics
  - Entrance Slit
Mechanical Design of Spectrometer Housings

UVES

VUVES
Spectrometers without Housing
Structural Performance - Stiffness

Eigenmodes > 78 Hz ⇔ 40 Hz (Requirement)
## Structural Performance - Strength

<table>
<thead>
<tr>
<th></th>
<th>5 g in X</th>
<th>5 g in Y</th>
<th>10 g in Z</th>
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<tbody>
<tr>
<td><strong>Max. Stress (MPa)</strong></td>
<td>26</td>
<td>24</td>
<td>56</td>
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<tr>
<td><strong>MoS Yield</strong></td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>MoS Ultimate</strong></td>
<td>1.6</td>
<td>1.8</td>
<td>0.2</td>
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</table>

Positive Margin of Safety
Thermal and Distortion Analyses
Thermal Architecture

No thermal link (e.g. heat pipe) required

- Detectors
- FEE
- HVPS
Optical Stability Analyses

- Assumptions
  - Temperature of the Protective Case: 20°C
  - Integration Temperature: 24°C (i.e. Delta T: 4°C)
  - Passive Optomechanics

- Lateral Shifts / Distortions in the Focal Plane
  - Translatory Displacement of Optical Elements
  - Rotation of Optical Elements (Most Critical)
  - Change of Properties i.e. Curvature and Line Spacing of the Gratings
Optical Stability Requirements - Sensitivity of Optical Elements

- Lateral Focus Shift of 10 μm at Detector
- Negligible Degradation of Focus Spot

<table>
<thead>
<tr>
<th></th>
<th>TX</th>
<th>TY</th>
<th>TZ</th>
<th>RX</th>
<th>RY</th>
<th>RZ</th>
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</thead>
<tbody>
<tr>
<td>Prism</td>
<td>&gt;100 μm</td>
<td>&gt;100 μm</td>
<td>&gt;100 μm</td>
<td>9“</td>
<td>&gt; 40“</td>
<td>&gt; 40“</td>
</tr>
<tr>
<td>Echelle Grating</td>
<td>&gt;100 μm</td>
<td>&gt;100 μm</td>
<td>&gt;100 μm</td>
<td>4“</td>
<td>4“</td>
<td>20“</td>
</tr>
<tr>
<td>Focus Mirror</td>
<td>&gt;100 μm</td>
<td>10μm</td>
<td>10μm</td>
<td>20“</td>
<td>5“</td>
<td>5“</td>
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<tr>
<td>Collimator</td>
<td>&gt; 100 μm</td>
<td>6 μm</td>
<td>10 μm</td>
<td>&gt; 40“</td>
<td>4“</td>
<td>2“</td>
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<tr>
<td>Detector</td>
<td>10 μm</td>
<td>&gt; 100 μm</td>
<td>10 μm</td>
<td>&gt; 10“</td>
<td>1“</td>
<td>&gt; 10“</td>
</tr>
</tbody>
</table>

Local Lateral and Rotational Stability Requirements
Trade Off
Active Aluminum Structure vs. Thermostable Structure

- Phase A Baseline
  - Thermally unstable Aluminum structure
  - 2 critical Focus Mechanisms (Collimator Mirror, Echelle Grating)
    - Compensation of thermal gradients, temperature change, (drift)
    - Multi axes adjustment with very high accuracies required

<table>
<thead>
<tr>
<th></th>
<th>Translatory Accuracy</th>
<th>Rotational Accuracy</th>
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<tr>
<td>Travel Range</td>
<td>200 µm</td>
<td>20 arcsec</td>
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<tr>
<td>Accuracy</td>
<td>5 µm</td>
<td>2 arcsec</td>
</tr>
<tr>
<td>Repeatability</td>
<td>2 µm</td>
<td>1 arcsec</td>
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</tbody>
</table>

- Critical In Orbit Operation to find best focus position
- 2 rotational and 1 translatory degree of freedom
## Trade Off

### Active Aluminum Structure vs. Thermostable Structure

- **Thermostable CeSiC Structure**

- **Integration Temperature:** 24°C

<table>
<thead>
<tr>
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<th>Ry [µrad]</th>
<th>Rz [µrad]</th>
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<td>0.7</td>
<td>3.3</td>
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<td>-0.5</td>
<td>-0.7</td>
<td>9.1</td>
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<td>-1.0</td>
<td>-1.6</td>
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<td><strong>VUV</strong></td>
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<td>-0.4</td>
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<td></td>
<td>-2.8</td>
<td>-0.8</td>
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<td>-0.6</td>
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<td></td>
<td>0.6</td>
<td>-0.7</td>
<td>-8.5</td>
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**Rotations of Optical Elements** (wrt local instrument reference frames)

- Echelle Grating
- Prism
- 1. Mirror
- 2. Mirror
- Detector
- Fine Guidance Detector
- Fine Guidance Mirror
- Grating
- 1. Mirror
- 2. Mirror
- Detector
- Fine Guidance Mirror
- Fine Guidance Detector
- Fine Guidance Mirror
OPTICAL STABILITY Analyses - Results

- Negligible Lateral Shift in the Focal Plane: < 20µm
- Acceptable Degradation without Active Alignment as Spectral Resolution comes with > 80 µm Distance in Detector Plane

⇒ Required Spectral Resolution without Active Control of Optical Elements
⇒ Complex Collimator and Echelle Grating Mechanisms Skipped !!
Mechanism Design
Grey Filter Mechanism -Design

■ Functionality
  ■ Use of different grey filters (neutral density and opaque filter)

■ Design Principle (PACS heritage)
  ■ Sliding crank for aperture cover

■ Kinematics
  ■ Travel Range 360 deg
  ■ Accuracy 10 arcmin
  ■ Moving Mass 0.2 kg (filter and rotor)
  ■ Aperture 35 x 45 mm (MCP area + margin)

■ Mechanism motor drive and equipment
  ■ Direct drive
  ■ Torquer Motor (TTL)
  ■ Magnetic Positioning

Demonstrator with 2 Positions (PACS)
Vacuum Shutter – Mechanism Design

- **Functionality**
  - Opening and closing of detector housing in vacuum
    (Note: No window applicable due to optical performance)
  - Leakage Rate < $10^{-9}$ mbar $\cdot$ dm³ / sec

- **Design Principle (ORFEUS heritage)**
  - Sliding crank for aperture cover

- **Kinematics**
  - Travel Range 60 mm
  - Accuracy $\pm$ 50 µm (equiv. 20 arcsec)
  - Moving Mass $<<$ 1 kg (aperture cover)
  - Aperture 35 x 45 mm (MCP area + margin)

- **Mechanism motor drive and equipment**
  - Spur Gear and Worm Gear
  - Stepper Motor (Phytron)
  - Mechanical end stops
Servo Mirror – Mechanism Design

- **Functionality**
  - Servo mirror steers main beam into redundant detector

- **Kinematics:**
  - Translatoric movement of servo mirror (40 x 50 mm²)
  - Travel Range 60 mm
  - Accuracy ± 50 μm (equiv. 20 arcsec)
  - Moving Mass 100 g (mirror)

- **Mechanism motor drive and equipment**
  - Spur Gear and Worm Gear
  - Stepper Motor (Phytron)
  - Mechanical end stops
In Orbit Calibration
In Orbit Calibration

- **MCPs**
  - Well Known Target Stars
    - nearly absolute radiance reference with high stability & homogeneity
    - Calibration radiance passing the entire telescope and spectrometers optics
  - Photo Response Non Uniformity by simulation of photon events (built in MCP Detector functionality)
  - Dark Signal Non Uniformity by closure of opaque filter (grey filter mechanism)

  ⇒ No Active in Orbit Calibration
  ⇒ Concept Qualified and Successfully Flown on ORFEUS

- **IFGS**
  - Photo Response Non Uniformity => not required
  - Dark Signal Non Uniformity by dark area pointing
Electronics and Detectors
Type of Observations

- Standby/OFF while other WSO-UV instruments work
- Acquisition of either UVES or VUVES science data
- Science data: Observation modes and data types
  - Full Frame transfer (Integration Mode)
    - spectral image with 4096 x 4096 Pixel
  - “Partial frame transfer” (Quicklook Mode)
    - user-defined part of spectral image
  - Event transfer (Photo Counting Mode)
    - X-, Y-Coordinates, Impulse height, Time stamp
- Instrument Calibration (Ground/In-flight)
- Instrument Alignment (Ground/In-flight)
- Test/Service/Maintenance
Redundancy – System Concept

Result of redundancy concept trade-off

<table>
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<th>Subunit</th>
<th>Nominal</th>
<th>Redundant</th>
<th>Comments</th>
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<td>ICU</td>
<td>x</td>
<td>x</td>
<td>Including telemetry/HK sensors</td>
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<tr>
<td>UVES MCP Detector</td>
<td>x</td>
<td>x</td>
<td>Including calibration means</td>
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<tr>
<td>VUVES MCP Detector</td>
<td>x</td>
<td>x</td>
<td>Including calibration means</td>
</tr>
<tr>
<td>UVES IFGS</td>
<td>x</td>
<td>-</td>
<td>Redundant electrical I/F</td>
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<tr>
<td>VUVES IFGS</td>
<td>x</td>
<td>-</td>
<td>Redundant electrical I/F</td>
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<tr>
<td>Mechanisms</td>
<td>x</td>
<td>x</td>
<td>Redundant coils and sensors only</td>
</tr>
</tbody>
</table>

- Cross-switch function for HIRDES power supply and data interface to S/C
- Common control unit for UVES and VUVES spectrometer
- Cold redundancy
- Switch over by relais command in case of failure occurrence
System architecture

Note: Sensors for Housekeeping inside Electrical boxes are not displayed!
MCP Detector Subunits

- FPA (main / red.)
- Front-end Electronics (main / red.)
- Detector Housing (main / red.)
- Vacuum Shutter (main / red.)
- Servo Mirror Mechanism
MCP Detector – Specification

- **Wavelength Range**
  - UV: 174.5 .. 310.0 nm
  - VUV: 102.8 .. 175.6 nm

- **Total gain**: 107 e- / Photon

- **Pulse height distribution**: FWHM < 80% (TBC)

- **MCP pore diameter**: 6 µm (TBC)

- **Open area ratio (OAR)**: 80%

- **Length to diameter ratio**
  - 80:1 (first and second single MCP)
  - 40:1 (third single MCP)

- **Active area**: 30x40 mm

- **Read out Method**: Wedge and Stripe Anode (WSA)

- **Photocathode material**: CsI, CsTe Depends on the wavelength range

- **Operational pressure**: < 1*10^-5 mbar

- **Lifetime on ground (after delivery)**: (TBD)

- **Lifetime in Space**: 10 years (TBC)
MCP Detector – Design concept

MCP detector design
- MCP assembly
  - Z-configuration
  - Integration at manufacturer favored
    (critical handling due to oxygen sensitivity, TBC)
- Mesh
  - Replacement by “wedged” first micro channel plate, TBC
- Material, Design/Layout equiv. to Orfeus
- WSA
  - Design/Layout equiv. to Orpheus

Potential Manufacturers
- MCP stack  Hamamatsu, Proxitronic, Burle,…
- WSA    IMT AG

MCP SEM image showing the micro channels (Burle Electro Optics, Inc.)

Orfeus Wedge-and-Stripe Anode (IAAT)
MCP Detector – Roadmap

Simulation Model under development (Matlab/Simulink; Mathcad)

- Impulse height distribution
- Anode Capacitance
- Output signal shape (WSA/CSA)
- Front-end electronics (functional level)
- Instrument SNR

Goals

- Verification of sensor performance
- Selection of components (MCP type, CSA, …)
- Optimization of Operational Parameters
MCP Front End Electronic – Specification

Functionality

- Charge-to-voltage conversion
- Signal shaping and amplification
- Pulse integrity check (e.g. pile up detection)
- AD conversion - 12Bit (14 bit goal)
- Centroid and pulse height calculation (see next chapter)
- Transfer of the science data to the ICU
  - Sampling rate: 5 MSPS (min) 10 MSPS (goal)
  - Oversampling > 3 x (TBC)
- Control and monitoring functions to the ICU (=master)

Performance Specification

- Signal amplification, Readout noise, Dynamic Range will be derived from MCP simulation
- Power Consumption <5W
MCP Front End Electronic – Design Concept

1 of 4 Analog channels
- Discharge & Baseline restore
- Control Logic
- Charge sensitive amplifier
- Pulse shaper
- ADC
- digital data processing (x,y,q)
- HK-ADC
- FEE Control
- ADC
- LVDS buffer

MCP detector
- Temperature Sensor
- Vacuum Sensor
- HV feedthrough

(Sealed) MCP Housing

MCP FEE Housing
- x1
- x2
- y1
- y2
- analog data
- connector to ICU
- connector to ICU

Vacuum Sensor

Temperature Sensor

HV feedthrough

to HVPS

to HVPS
MCP Front End Electronic – Roadmap

Simulation
- Input from MCP simulation/measurements
- Electrical Model (e.g. PSpice) for discrete components
- Implement different concepts for
  - pulse identification
  - pile-up detection
  - CSA reset
- Design evaluation of different concepts
  - Performance analysis
  - Concept trade
  - Optimization of design

⇒ Breadboard
⇒ Selection of realization concept
  - discrete circuit
  - ASIC
⇒ Selection of components

MCP FEE ASIC from IMEC/FillFactory/KU Leuven (ESA - ESTEC GSTP)
MCP Detector – Housing design

Vacuum compartment
- MCP assembly
- HV harness to MCP-stack
- LV harness to WSA

Ambient pressure compartment
- MCP front-end electronic (dissipating approx. 5W)
- Vacuum shutter motor control electronics
- EMI shield between FEE and Motor Control Electronic
- I/F to ICU and spectrometer (alignment and thermal control)
MCP Detector – Housing Design

- Pressure < $10^{-5}$ mbar vacuum or inert gas ($N_2$)
- Envelope: 14 x 12 x 10 cm$^3$
- Wall thickness: 3 mm
- 50% of volume for MCP assembly, feed throughs, harness, ...

![Diagram of MCP Detector with labels](image)
IFGS Detector – Specification

- IFGS data for compensation of spectral image jitter on the MCP detectors due to telescope movement during exposure
  ⇒ increased HIRDES spectral accuracy
- Standard algorithm for 2D – centroid calculation
- Identical IFGS Detectors for UV and VUV

Key requirements
- Detector wavelength range visible
- Required detector pixel size ≤ 15µm (10µm goal)
- Number of pixels 100 x 100 (optional 20x20 window)
- Frame rate ≥ 1 Hz
- Programmable exposure time 0.1 – 10 sec (bright/faint stars)
- Centroid calculation performed by ICU
IFGS Detector – Design Trade Off

- CMOS vs. CCD detector – Selection criteria
  - Sensor SNR -> Simulation of detector chain
- SNR simulation results
  - Limited Number of signal electrons (~ incoming photons) by FWC of CMOS detector due to high dark current and high integration times
  - Worst-case SNR for faint stars with 10sec exposure: SNR = 20
  - SNR improvement by detector cooling (dark current reduction)
- Advantages of CMOS detectors wrt HIRDES instrument design
  - Low power dissipation
  - Radiation hardness by design
  - Programmable functions like
    - windowing
    - gain
    - offset
  - On-Chip data conversion
  - Ease on integration (no difficult biasing or timing pattern)
  - Costs
IFGS Detector – Design Concept

internal Fine Guidance Sensor UVES / VUVES

Cypress/FillFactory STAR1000 CMOS detector

- x,y address decoder
- 2D-imaging array
- column amplifier
- PGA
- 10 Bit ADC

- Readout control (exposure, windowing, ...)
- Fixed Pattern Noise (FPN) correction

IFGS FPA Control

- HK-ADC
- local power distribution

IFGS I/F

IFGS FEE housing

- LVDS buffer (serializer)
- RS422 (UART)

FPA housing

- FPA Temperature sensor

local power distribution

IFGS FEE housing
ICU – Technical Specification

- Scientific data acquisition
- Instrument/Subsystems control and monitoring functions incl. status supervision
- Housekeeping data acquisition
- Communication protocol of the 1553B MIL-Bus
- Telecommand and telemetry (TC/TM) functions
- Self test and failure detection, insulation and recovery (FDIR) functions
- Software maintenance functions incl. software download to other controllers (if applicable)

Data types:

<table>
<thead>
<tr>
<th>Data Type</th>
<th>Subtype</th>
<th>Parameter</th>
<th>Data Format</th>
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<tr>
<td>Science Data</td>
<td>Photon Count (Event transfer)</td>
<td>X, Y coordinate</td>
<td>X, Y: 16 Bit</td>
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<td>Impulse height</td>
<td>Q: 8 Bit</td>
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<td>Timestamp</td>
<td>T: 24 Bit</td>
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<td></td>
<td>Integration (Full Frame transfer)</td>
<td>Pixel</td>
<td>4096 x 4096x16Bit</td>
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<td>Quicklook (Partial Frame transfer)</td>
<td>User defined (compressed) pixel</td>
<td>n x 16Bit</td>
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<td>IFGS Data</td>
<td>Raw Data</td>
<td>Pixel</td>
<td>100x100x16Bit</td>
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<td></td>
<td>Corrected Image Data</td>
<td>Pixel</td>
<td>100x100x16Bit</td>
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<td></td>
<td>Centroid Data</td>
<td>X, Y coordinate</td>
<td>X, Y: 16 Bit</td>
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<td></td>
<td>Intensity</td>
<td>I: 16 Bit</td>
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<td>Telecommands</td>
<td>Analog or Digital TC</td>
<td>Number of Parameters TBD</td>
<td>32 Bit (TBC)</td>
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<td>Telemetry</td>
<td>Analog or Digital TC</td>
<td>Number of Parameters TBD</td>
<td>32 Bit (TBC)</td>
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<tr>
<td>Control Data (internal)</td>
<td>Analog or Digital TC</td>
<td>Number of Parameters TBD</td>
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<td>Monitoring Data (internal)</td>
<td>Analog or Digital TC</td>
<td>Number of Parameters TBD</td>
<td>32 Bit (TBC)</td>
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</table>
ICU – „Excerpt“ of Data Budget

<table>
<thead>
<tr>
<th>Interface/Unit</th>
<th>Data Format</th>
<th>Exposure Time (Duration of acquisition cycle)</th>
<th>Data per Acq. Cycle</th>
<th>Transfer to S/C via MIL-Bus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photon Count (Event Transfer)</td>
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</tr>
<tr>
<td>Bright Star</td>
<td></td>
<td>110s assuming an incoming flux $10^{-11}$ erg/cm²/sec/A</td>
<td>Photon rate 327.000 cts/sec</td>
<td>274 MB 3075s Intermediate storage required!</td>
</tr>
<tr>
<td>VUVES</td>
<td>X(16 Bit), Y(16 Bit), Q(8 Bit), t(24 Bit)</td>
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<td></td>
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</tr>
<tr>
<td>UVES</td>
<td></td>
<td>250s assuming an incoming flux $10^{-11}$ erg/cm²/sec/A</td>
<td>Photon rate 208.000 cts/sec</td>
<td>397 MB 4446s Intermediate storage required!</td>
</tr>
<tr>
<td>Faint Star</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VUVES</td>
<td></td>
<td>11000s assuming an incoming flux $10^{-13}$ erg/cm²/sec/A</td>
<td>Photon rate 5.000 cts/sec</td>
<td>420 MB 4702s</td>
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<tr>
<td>UVES</td>
<td></td>
<td>26000s assuming an incoming flux $10^{-13}$ erg/cm²/sec/A</td>
<td>Photon rate 1.500 cts/sec</td>
<td>298 MB 3335s</td>
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<tr>
<td>Integration (Full Frame Transfer)</td>
<td>4096 x 4096x16Bit</td>
<td>see above</td>
<td>32 MB</td>
<td>356s</td>
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<tr>
<td>Quicklook (Partial Frame Transfer)</td>
<td>n x 16 Bit</td>
<td>see above</td>
<td>1.6 MB W/C</td>
<td>approx. 16s W/C</td>
</tr>
</tbody>
</table>

- HIRDES science data rate to high for real-time data transfer to S/C if,
- Observation of Bright stars
- Photon Count (Event Transfer)
- Other observation modes: Transfer of Science Data after integration/compression in to S/C

⇒ “Design driver” for ICU architecture
ICU – Design Concept
ICU – Design Concept

Data Processing Unit

- Mosaic 20 DPU from Astrium
- DSP TSC21020E clocked at 20MHz
- 128Kx48bit program memory
- 128Kx40bit data memory
- optional Data Memory Bus Extension
LVPS Technical Specification

- 15 voltages to Subunits
  - ICU
  - MCP (UVES and VUVES)
  - IFGS (UVES and VUVES)
  - Motor Control Electronics

- Prevention of S/C power errors to propagate into HIRDES instrument and vice versa
- Relay command to switch between HIRDES power interface from S/C interface
- Relay command to the S/C (“Turn LVPS ON/OFF”)
LVPS Design Concept

Cross switch (+27V)

Nominal System
- Relais Command LVPS Nom ON
- HK ADC
- Latching Input Current Limiter
- Low Voltage Converter

Redundant System
- Relais Command LVPS Red ON
- HK ADC
- Low Voltage Converter

Feedthrough of relais commands:
- HVPS Nom ON
- HVPS Red ON
- ICU Reset

15 output voltages to 7 sub-units

RS422 to ICU

Relays Commands:
- CrossSwitch LVPS
- LVPS Nom ON
- LVPS Red ON
- HVPS Nom ON
- HVPS Red ON
- ICU Reset

+27VNom
27VN Nom RTN
27VRed
27V Red RTN

15 output voltages to 7 sub-units

RS422 to ICU

S/C

Redundant System: AtCrossSwitch LVPS AtLVPStNom On AtLVPStRed On AtHVPStNom On AtHVPStRed On AtICUtReset

Nominal System: AtCrossSwitch LVPS AtLVPStNom On AtLVPStRed On AtICUtReset
HVPS Technical Specification

- 16 output voltages to the
  - MCP Assembly UVES
  - MCP Assembly VUVES
- Interlock to prevent the MCP from destruction due to false operation
- Prevention of S/C power errors to propagate into HIRDES instrument and vice versa
- Relay command to the S/C ("Turn HVPS ON/OFF")
HVPS Design Concept

Nominal System
- Relais Command HVPS Nom ON
- EMI Filter
- Latching Input Current Limiter
- High Voltage Converter
- HK ADC
- HVPS control
- to MCP’s

Relais Commands: At HVPS Nom ON
- +27V_Nom
- 27V_Nom_RTN

Relais Commands: At HVPS Red ON
- +27V_Red
- 27V_Red_RTN

Redundant System
- EMI Filter
- Latching Input Current Limiter
- High Voltage Converter
- HK ADC
- HVPS control
- to MCP’s

16 output voltages to MCP detectors

LVPS

Power output

RS422

to ICU

pressuresensor
Budgets
# Mass & Power Budget

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Mass [kg]</th>
<th>Power [W]</th>
<th>Comments</th>
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<tbody>
<tr>
<td>UV / VUV Spectrometer</td>
<td>29.8 / 31.1</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>UV / VUV Detector</td>
<td>22.8 / 22.8</td>
<td>6.2</td>
<td>Alternate operation</td>
</tr>
<tr>
<td>UV / VUV IFGS</td>
<td>2.6 / 2.6</td>
<td>2.7</td>
<td>Alternate operation</td>
</tr>
<tr>
<td>HVPS</td>
<td>4</td>
<td>5</td>
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<td>External Electronics</td>
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<td>Margin (20 %)</td>
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<td>13.5</td>
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<tr>
<td>Total</td>
<td>151.2 (&lt;155)</td>
<td>81.1 (&lt;150)</td>
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</table>

**Power Budget:**
- Nominal mode (= Science Mode)
- Peak Power: 119 W
Design, Development and Verification Plan
Model Philosophy

- **Breadboarding:**
  - MCP stacks and FEE
  - Mirror / Grating / Coating demonstrator-tbc

- **STM:**
  - UV/VUV Structures with thermomechanical dummies for electronics, mechanisms, detectors;

- **EQM:**
  - Mechanisms, MCP / CMOS Detectors, Electronics

- **PFM:**
  - Full Flight Hardware with refurbished STM

- **FS:**
  - Repair kits for critical items (bearings, etc.)
  - MCP Spare models (UV, VUV) -> refurbished EQM
  - IFGS Detector Spare models -> refurbished EQM
  - Mechanisms Spare models -> refurbished EQM
Preliminary Risk Assessment (top ranking risks)

<table>
<thead>
<tr>
<th>Element</th>
<th>Risk Type</th>
<th>Risk Mitigation Strategy</th>
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<tbody>
<tr>
<td>MCP</td>
<td>Schedule risk due to customized MCP development and technical risks (quantum efficiency; Coatings)</td>
<td>- Selection of experienced stacks developer (Hamamatsu); coating facilities, etc.</td>
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<tr>
<td></td>
<td></td>
<td>- Use of FEE heritage partly available at IAAT</td>
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<tr>
<td></td>
<td></td>
<td>- Early MCP procurement &amp; bread boarding</td>
</tr>
<tr>
<td>IFGS</td>
<td>Schedule risk due to customized CMOS development</td>
<td>- Selection of experienced CMOS developer (Fill Factory)</td>
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<td></td>
<td></td>
<td>- Adequate Subcontractor control;</td>
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<tr>
<td>Structural materials and Hybrid Structure</td>
<td>Technical risk due to missing space qualification</td>
<td>- Extensive technology programs performed by ECM (ESA contract)</td>
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<tr>
<td>(CeSiC; Invar, Quartz Glas)</td>
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<td>- Qualification to be performed in phase B</td>
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<tr>
<td></td>
<td></td>
<td>- Potential fallback: Space qualified C/SiC (Astrium F); but not considered for baseline approach</td>
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</table>
Project Development Scheme - Phase B1 Bridging

- Evaluation of System Requirements and System Specification
- System Requirements Review
- Engineering
  - Electrical
  - Structural and Thermal
  - Optical
  - AIV
  - Mechanisms
  - Detectors (MCP, IFGS)
  - Interfaces to S/C
- MCP Breadboarding (Stacks, coating, QE)
- Final Presentation Review
## B1 Bridging/B2/C/D/E Master Schedule - HIRDES

### HIRDES Phase B2/C/D/E Schedule

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<thead>
<tr>
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</table>
HIRDES Schedule Planning – Meetings and Milestones

- Phase B1 Bridging (03.07.06-29.12.06)
  - KoM (Virtual date) 03.07.2006
  - SRR 15.09.2006
  - FP 20.12.2006

- Phase B2 (15.03.07-28.09.07)
  - KoM 15.03.2007
  - PDR 17.09.2007

- Phase C/D (01.10.07-28.10.2010)
  - KoM 01.10.2007
  - DRB (EQM/STM Delivery) 02.09.2008
  - CDR 22.09.2008
  - TRR 19.08.2009
  - FAR (PFM Delivery) 27.01.2010
  - Launch (28.10.2010)

Contingency planning for PFM MAIT: 8 weeks
## Phase B1 Documentation

<table>
<thead>
<tr>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>Preliminary Design Description (Mechanics, Electronics, Mechanisms, Detectors, Thermal and Structural Analyses)</td>
</tr>
<tr>
<td>Preliminary S/W Architecture and S/W Implementation Plan</td>
</tr>
<tr>
<td>Preliminary ICD (mechanical, electrical, optical, S/W) and Budgets (mass, power, data)</td>
</tr>
<tr>
<td>Preliminary PA Plan</td>
</tr>
<tr>
<td>DDV Plan (Implementation planning, Model Philosophy, Verification Analyses/Tests, Schedule, Deliverable Items)</td>
</tr>
<tr>
<td>Phase B2, C/D Cost Assessment</td>
</tr>
<tr>
<td>Final Documentation (Final Report, Document Control Sheet)</td>
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<tr>
<td>Preliminary Optical Performance Analyses; Spectrometer Layout;</td>
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### Phase B1 – Internal Documentation

<table>
<thead>
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<th>Document Type</th>
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<tbody>
<tr>
<td>Instrument Requirements Specification</td>
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<tr>
<td>MCP Requirements Specification</td>
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<tr>
<td>IFGS Detector Requirements Specification</td>
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<tr>
<td>MCP Stack RFQ</td>
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