PAYLOAD DESIGN | ENG 4360

Final Design Review (Group C)

An Analysis of the Seasonal Variation of CH_4 and CO_2 Concentration Levels in the Mars Atmosphere

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TEAM INTRODUCTION

Yaseen Al-Taie
Head of Design

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Project Manager

Pavithra Kugarajah
Head of Research

REQUIREMENTS TABLE

Requirement	Assumption(s)	Verification / Validation
The payload should detect carbon dioxide (CO_2) and methane (CH_4) concentration levels	Payload will be able to detect both trace gases simultaneously	Spectrometer detection ability will be tested with carbon emissions during the pre-launch time period
The payload should have a lens that enables detection of the wave fronts at a precise measurement	Specific lens is required for low altitudes since we are doing measurements at low altitudes	Lens will be tested out on carbon emissions and the one enabling the most precise measurement will be used
The payload should filter out a specific spectra of wavelengths	Filter will constrain range in a way that will endorse accurate detection	Bandpass filter that filters out all wavelengths except corresponding values
The payload should have thermal restraints based on its operational functions.	Coating and material choice should be sufficient enough for thermal control / configuration	Testing will be done via simulation and NX software tools and expected environmental conditions of Mars
The payload should have a focal length of 100mm ($\pm$ 5mm)	Defined focal length will restrict pointing system as well	Measurements will be verified through expected values, and positional verification.

REQUIREMENTS TABLE (CONT'D)

Requirement	Assumption(s)	Verification / Validation
The payload should occupy a laser that is set to emit near the absorption line of the gases	Emitting the laser near the absorption line can be enabled by temperature and current configuration	Testing laser and verifying that its emission is analogous to the trace gases.
The payload should have environmental neglecting processes on the system	Materials used with reference to thermal constraints won't hinder its stability with the environment	Testing the payload in a vacuum that simulates the environment of the Mars surface.
The payload should have column measurements upwards of 5km from the surface	Defined column measurement parameters will define field of view as well; concentrations are abundant at low altitudes	Analyzing the spectrums produced during the testing period with reference to the expected data of the same altitudes on Earth
The payload should have a data processing and data relay system that can handle data, graphs, spectrum, etc.	Payload should have enough processing power and there will be no lag during the spectrogram data acquisitions	Relaying data will be tested and monitored, and backup data will be saved through the MRO satellite system.

POTENTIAL SOLUTIONS

NDIR
Nondispersive Infrared Sensor

FTIR
Fourier Transform Infrared Spectrometer

APIMS
Atmospheric Pressure Ionization Mass Spectrometer

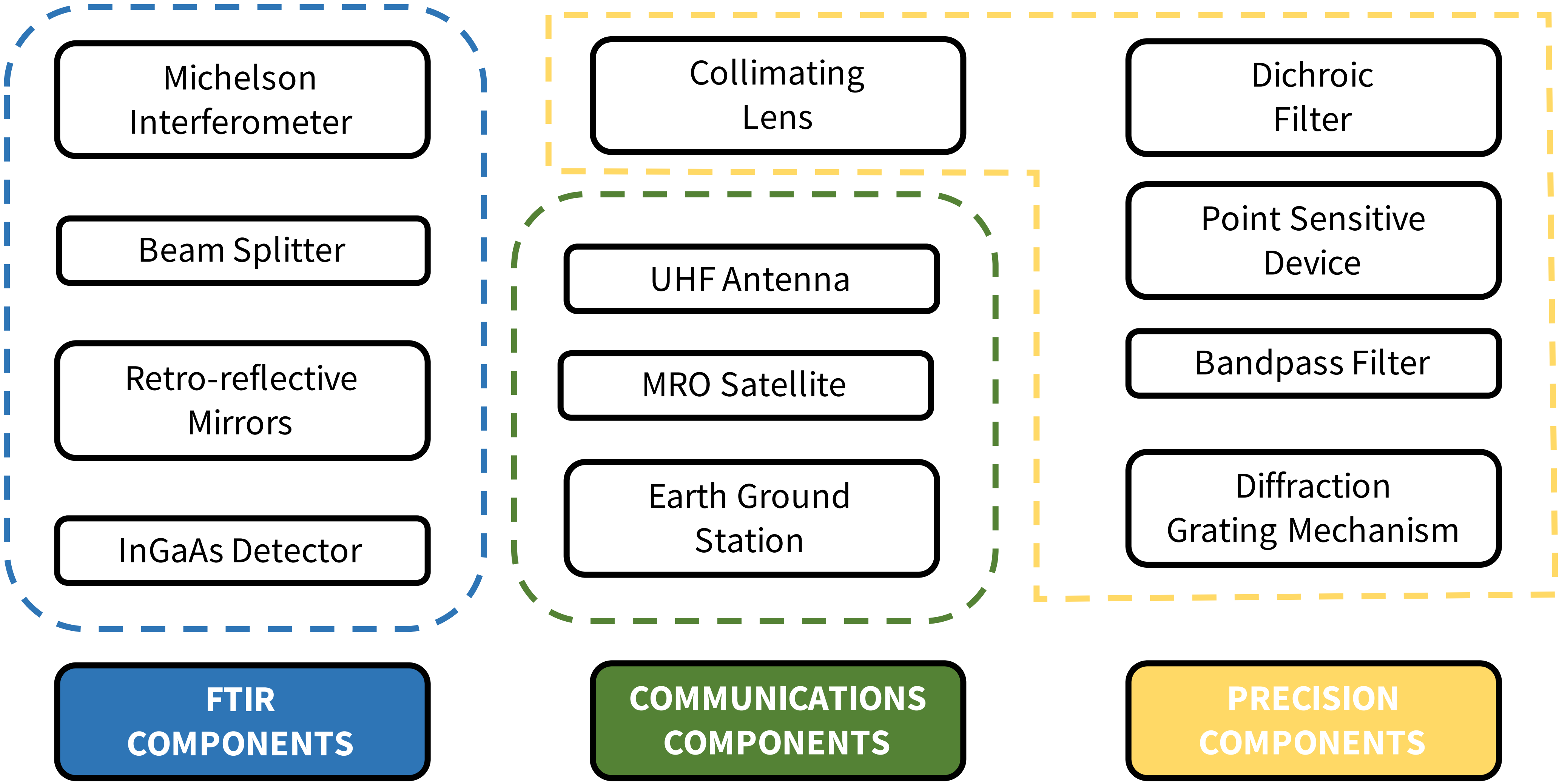
IASI
Infrared Atmospheric Sounding Interferometer

AMULSE
Atmospheric Measurements by Ultra-Light Spectrometer

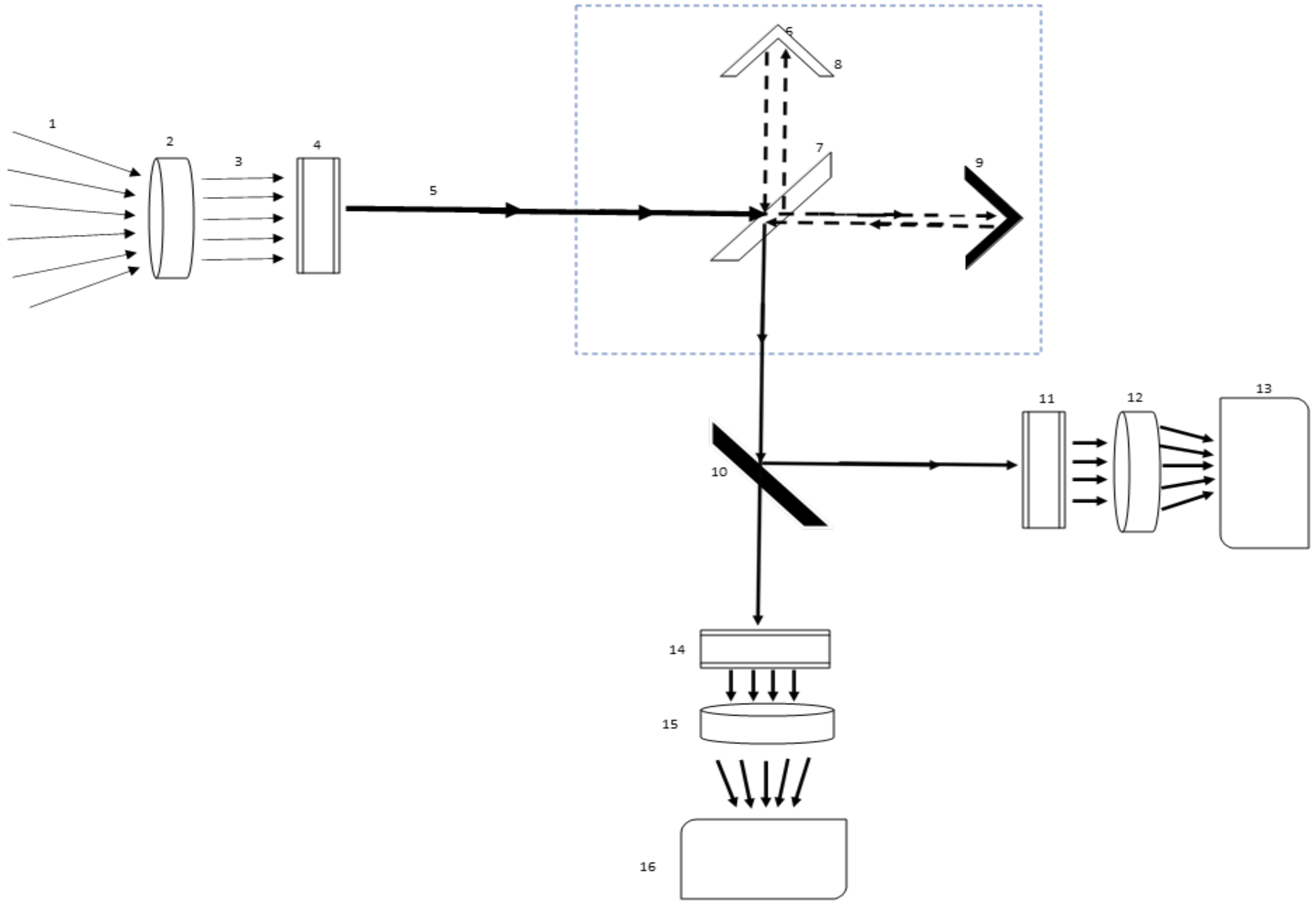
TRADE STUDY ANALYSIS

	NDIR	APIMS	AMULSE	FTIR	IASI
Detection Methodology / Hindrances	Cross-sensitive at low concentrations (H_2O specific)	Dryers used to remove water before detection (similar to NDIR)	WMS technique through vertical profiling	Detector produces an interferogram based off of mirror position	Collects vertical structure of the atmosphere temperature and humidity
Filtering / Constraint Method	Multiple sensors for simultaneous measurements	Quadrupole Mass Filter (filters out by mass)	No filtering method applicable	No filtering method present (can be incorporated)	Infrared part of EM spectrum only
Measurement Precision	Offset and linear correction required (0-10,000ppm)	Based on mass-to-charge ratio of detected ions; low fluxes can produce large error	Ideally: 0.96ppm in 1 second of integration time	SNR ratio is improved upon by multiplex and its throughput; precision is thorough as well	Unprecedented accuracy; 12km altitude over 2200km horizontal field of view
Relative Power of System	High-power consumption	High-power consumption	High-power consumption	High power consumption	High power consumption

CRITICAL COMPONENTS OF SYSTEM



DESIGN (TECHNICAL) OVERVIEW



Concentration Measuring Methodology

(1) Incident Light
(2) Collimating Lens
(3) Collimated Light
(4) Interference Filter
(5) Filtered Light
(6) Michelson Interferometer
(7) Beam Splitter
(8) Fixed Mirror
(9) Moving Mirror
(10) Dichroic Beam Splitter
(11) Bandpass Filter
(12) Focusing Lens
(13) InGaAs detector (CO_2)
(14) Bandpass Filter
(15) Focusing Lens
(16) InGaAs detector (CH_4)

CONSTRAINTS/SPECS DENOTATION

DESIGN SPECIFICATIONS

- *Field of View*: 49.3 degrees
- *Aperture*: 50mm
- *Focal Length*: 100 mm @ f/2 (*with an Effective focal length* - 102.6 mm)
- *Spot Size*: 30 x 10^{-9} m
- *Quality Factor*: 1.9
- *Channel (InGaAs)*: C and L
- *Spectral Resolution*: 0.5 cm^{-1}
- *Spatial Resolution*: 10 km x 10 km
- *Point Spread Function*: 1600 nm

OPERATIONAL CONSTRAINTS

- Moving Mirrors
- Diffraction Grating
- Focal Length –> Focusing Length –> Pointing System
- Voice Coil Motors
- Data Relay Configuration
    - Lag Control
    - Data Size Control
- Noise Control
    - Dark Noise
    - Shot Noise

ENVIRONMENTAL AND THERMAL CONSTRAINTS

- Solar Arrays are made of 80% solar cell; 20% Aluminum 6061 (used for additional power supply)
- Lens window made up of ULE Glass
- Thermal Control Methodology:
    - Thermoelectric Radiators (Primary Control)
    - Warm Electronic Box
    - Gold Paint Coating
    - Aerogel Insulation
    - Heat Rejection System (not to overheat)

COST ANALYSIS

Part	Description	Cost
Payload	Spacecraft landing on the Surface of Mars; mainly an FTIR Spectrometer	~ 20,000
Structure	Aluminum 6061 Frame	~ 400,000
Communications	Ground Station Kit + UHF Antenna	~ 120,500
Power	GaAs Cells + High Energy Density Battery	~ 8000
Thermal Control	- Heaters + WEB	~ 1,000
Total (Euros)		549,500
Total (CAD)		~ 825,000

Note: Launch Segment, Ground Segment and Operations Cost are not included

PROJECT TIMELINE (PHASES)

PROJECT DESIGN PHASE

September 2018
- Start of the Project
- Mission Objective Defined
- Letter of Intent

October 2018
- Market Research
- Initial Requirements / Trade Study
- DDR Presentation

November 2018
- Stakeholder Input
- Design Overview
- Component Configuration
- Environmental & Constraint Study
- FDR Presentation

MISSION / PAYLOAD DESIGN PHASE

December 2018
- Final Report Documentation
- Design Verification
- Cost Analysis / Risk Assessment
- Mission Approval

2019-2021
- Payload Assembly
- Launch Study
- Further Risk Assessment
- Payload Testing and Final Verification

2022-2025
- Launch of Spacecraft
- Payload Monitoring & Data Acquisition
- Analysis & Further Applications