

FREE SPACE OPTICAL GROUND STATION SOLUTIONS

Atmospheric Characterization for Reliable Ground-to-Space Laser Communications

Solmirus Corporation | Miratlas SAS

THE CHALLENGE

Free Space Optical (FSO) communication delivers unmatched bandwidth, security, and spectrum independence — but the atmosphere is the enemy. Clouds block. Turbulence scatters. Absorption attenuates. Continuity of service depends on knowing your atmospheric channel before you commit to a link.

THE SOLUTION

The Solmirus ASIS M1i delivers calibrated, measurement-grade infrared all-sky imaging — a critical atmospheric data layer for FSO operations. Combined with the Miratlas SkyMonitor, the result is the only fully integrated solution on the market covering essential CCSDS-recommended parameters for Free Space Optical communications.

THE FSO ATMOSPHERIC CHALLENGE

Free Space Optical communication offers bandwidth capacities that dwarf traditional RF systems, with inherent security advantages and zero spectrum licensing requirements. The rapid growth of LEO/GEO satellite constellations — and the demand for high-throughput direct-to-Earth optical downlinks — has made FSO the technology of choice for next-generation space-ground communications.

But the atmosphere introduces fundamental challenges that cannot be engineered around — only measured, characterized, and managed:

- Cloud cover is the primary availability limiter for FSO links. Even thin cirrus can cause link outages. Real-time all-sky cloud imaging is essential for link scheduling, handover decisions, and site diversity management.
- Atmospheric turbulence causes beam wander, scintillation, and wavefront distortion — directly degrading link quality and available bandwidth. Turbulence intensity varies dramatically with time of day, season, and site geography.
- Water vapor absorption and aerosol attenuation impose wavelength-dependent transmission losses that must be measured and modeled for accurate link budget calculations.
- Site selection for Optical Ground Stations (OGS) requires long-baseline statistical data on cloud cover, turbulence, and atmospheric transmission — data that simply does not exist for most candidate sites.

Continuity of service can only be ensured through site diversity and precise, real-time understanding of the atmospheric communication channel. Unlike fiber optics, the atmosphere is an ever-changing propagation medium inducing continuous bandwidth variations of the theoretical link capacity.

The Consultative Committee for Space Data Systems (CCSDS) — the standards body for space communications — has published the Magenta Book defining the recommended atmospheric measurement parameters for FSO ground station operations. Meeting these requirements has historically required multiple expensive, specialized instruments. Until now.

THE CCSDS MAGENTA BOOK STANDARD

The CCSDS Magenta Book ("Optical Communications Physical Layer" series) defines the atmospheric measurement requirements for ground stations supporting Free Space Optical communications links. These parameters fall into two categories: directly measured physical quantities and derived data products.

The table below shows Magenta Book parameters relevant to FSO operations, the Solmirus ASIS M1i coverage, and where our Miratlas partnership fills the remaining gaps to provide a complete compliant solution.

Data Product / Measurement	Units	Update (s)	Range	Accuracy	Precision	Coverage
MEASURED PARAMETERS						
Temperature	°C	≤60	-80 to 60	0.3	0.10	ASIS/MASM
Relative Humidity	%	≤60	0 to 100	2.0	0.10	ASIS/MASM
Wind Speed	m/s	≤60	0 to 75	0.3	0.10	MASM
Wind Direction	degrees	≤60	0 to 360	3.0	1.00	MASM
Surface Air Pressure	hPa	≤60	500 to 1,100	0.5	0.10	MASM
Solar Insolation	W/m ²	≤60	0 to 1,800	1.0	0.10	**
Rainfall Rate	mm/h	≤60	0 to 1,800	6.0	0.60	MASM
Backscatter	1/sr-m	≤6	0 to 10,000 E-8	10.0	1.00	**
Sky Radiance	W/m ²	≤30	0 to 20 (W/m ² /μm)	0.1	0.05	ASIS
Fried Coherence Length (r ₀)	cm	≤60	0.5 to 50	7%/11%/12%	—	MASM
Aerosol Attenuation	dB	≤60	0 to 100	0.5	0.10	**
DERIVED DATA PRODUCTS						
Cloud Base Height	m	>2	0 to 10,000	±(4.6m or 0.25%)	—	**
Cloud Mask	—	≤30	0 to 1	2%	0.1%	ASIS
Cloud Attenuation	dB	≤30	0 to 10	10%	0.50	ASIS
Skydome Cloud Fraction	%	≤30	0 to 100	2%	0.1%	ASIS
Skydome Cloud Correlation	—	≤30	-1 to +1	—	0.01	ASIS
Isoplanatic Angle	μrad	≤60	0.3 to 50	1%	—	MASM

* Instrument station P/N: SOLMA-FSOIC.02A parameters shown. Sky Radiance range 0–20 W/m²/μm at ≤30s cadence. Fried coherence length and isoplanatic angle provided by Miratlas C-DIMM/SSM/SHABAR instruments.

** Available with addition of 3rd party instrumentation (COTS), however not essential for operations.

ASIS M1I — ALL SKY INFRARED IMAGING SYSTEM

The Solmirus ASIS M1i is the core infrared imaging component of the FSO ground station solution. It delivers continuous, calibrated, measurement-grade infrared all-sky images at ≤30 second cadence — providing the cloud detection and sky radiance data that FSO operators depend on for real-time link management and site characterization.

The ASIS M1i is purpose-built for 24/7 autonomous outdoor operation. Unlike visible-only sky cameras, it operates in complete darkness — making it the only viable solution for continuous FSO link support through night passes.

Why Infrared for FSO?	FSO-Specific Capabilities
<p>Visible-light cameras cannot detect optically thin clouds — precisely the cloud type most likely to cause unexpected FSO link degradation. The ASIS M1i operates in the 10–12 micron thermal infrared band, detecting cloud thermal emission regardless of sunlight availability.</p>	<p>Sky radiance: 0–20 W/m²/μm range, ≤30s cadence, 0.1 W/m²/μm accuracy</p>
<p>This means:</p> <ul style="list-style-type: none"> ◦ Detection of thin cirrus and sub-visual clouds invisible to visible cameras ◦ True 24/7 operation — day and night, no illumination dependency ◦ Calibrated sky radiance measurements for quantitative cloud characterization ◦ Blackbody-referenced calibration for measurement-grade accuracy ◦ Cloud temperature and emissivity characterization 	<p>Cloud mask: 2% accuracy, 0.1% precision — clear/low-emission/high-emission classification</p>
	<p>Skydome cloud fraction: 0–100%, 2% accuracy</p>
	<p>Cloud attenuation estimation: 0–10 dB, 10% accuracy</p>
	<p>Skydome cloud correlation for temporal link prediction</p>
	<p>Clear-sky radiance baseline with MODTRAN-referenced precipitable water vapor</p>
	<p>180° field of view covers entire sky dome simultaneously</p>
	<p>Real-time web UI with data API for integration into OGS control systems</p>

Instrument Specifications

IR Focal Plane Array	640×480, internal shutter
Spectral Band	10–12 micron (thermal infrared)
Field of View	180° — full hemispherical all-sky
Lens	Ruggedized carbon-coated fisheye IR lens
Measurement Cadence	≤ 30 seconds
Sky Radiance Range	0 to 20 W/m ² /μm
Sky Radiance Accuracy	0.1 W/m ² /μm

Calibration System	Dual blackbody mast (heated + ambient) + integrated hemispherical blackbody hatch
Motorized Hatch	270° rotation — automated calibration sequences
Enclosure	NEMA 4 stainless steel, powder-coated weatherproof
Dimensions	12"W × 16"D × 28"H
Weight	~35 kg (without case), ~60 kg (with case)
Operating Temperature	-20°C to +55°C external; Peltier-cooled internal
Thermal Management	Peltier cooling system with internal temperature monitoring
Control System	Ruggedized Intel ARM-based embedded computer
Interface	Web-based UI; Fiber or Ethernet connectivity
Power	9A/125VAC or 4.5A/250VAC
Installation	Crane lift ears; leveling indicator; stainless steel base with mounting holes

ASIS M1I DATA PRODUCTS

The ASIS M1i produces a rich suite of standard and custom data products, all delivered through a real-time web interface and accessible via API for integration into OGS control systems and link management software.

Data Product	Availability	Type ID	Measurement Detail	Units
Raw/Difference Image	Standard	DIFF	Raw instrument values	Instrumental Counts
Calibrated/Actual Radiance	Standard	RAD_ACT	Spectral radiance	W/m ² /μm/sr
Normalized Radiance	Standard	NR	Spectral radiance normalized by ambient radiance	Unitless
NR vs. Airmass	Standard	GET_AM_PLOT	Diagnostic plot — link quality indicator	N/A
Clear Sky Subtracted NR	Standard	CS_SUB	Normalized radiance with clear sky removed — cloud signal isolation	Unitless
Cloud Mask	Standard	CS_SUB_MASK	Clear, low-emission, and high-emission cloud classification	1, 2, 3
Brightness Temperature	Standard	BT	Cloud/sky temperature from spectral radiance	Kelvin
Optical Depth	Custom	OD	Cloud optical depth — link attenuation estimation	dB
Color Temperature	Custom	CT	Multi-filter spectral analysis (requires optional filter set)	Kelvin

Standard products are included with all ASIS M1i instruments. Custom products are available as optional additions depending on configuration. All data products are time-stamped and archived locally with export via web UI or API.

THE MIRATLAS PARTNERSHIP — COMPLETING THE SOLUTION

The Solmirus ASIS M1i addresses critical FSO atmospheric requirements — continuous, calibrated cloud detection and sky radiance. The Miratlas SkyMonitor completes the picture by adding atmospheric turbulence characterization and absorption measurement, delivering a solution that covers CCSDS-recommended FSO parameters from a single integrated deployment.

Solmirus and Miratlas formalized a strategic distribution agreement in December 2025. This partnership delivers the only integrated FSO atmospheric characterization solution on the market — combining Solmirus' calibrated infrared all-sky imaging with Miratlas' turbulence and absorption technologies.

Miratlas SkyMonitor Adds:	Combined Solution Coverage:
Fried coherence length (r_0) — turbulence strength measurement by day and night (C-DIMM/SSM/SHABAR)	Sky Radiance (cloud detection)
Isoplanatic angle — beam wander and AO system sizing parameter	Cloud Mask (24/7)
Atmospheric turbulence profiling — C_n^2 measurements	Cloud Fraction
Water vapor absorption — transmission loss quantification	Cloud Attenuation
Irradiance measurement	Brightness Temperature
Machine learning-based short-term atmospheric forecasting	Optical Depth
Global SkyMonitor network data for site comparison and OGS network design	Fried Coherence Length
LaserCom Pathfinder service — site selection modeling and simulation	Isoplanatic Angle
<i>The SkyMonitor is compact (20x20cm, 3kg), easy to deploy, and connects to Miratlas' cloud data platform for historical analysis and forecasting.</i>	Turbulence (C_n^2)
	Water Vapor
	Link Forecasting
	Site Selection Tools

FSO OPERATIONAL USE CASES

Optical Ground Station Operations	Link Budget & System Design
FSO terminals require continuous real-time sky awareness to manage link availability, schedule satellite passes, and execute handover between OGS sites. The ASIS M1i delivers:	Accurate FSO link budgets require measured, site-specific atmospheric transmission data rather than climatological estimates. The ASIS M1i and SkyMonitor together provide:

<ul style="list-style-type: none"> ◦ Real-time cloud masks at $\leq 30s$ cadence for pass-by-pass link availability prediction ◦ Advance warning of cloud encroachment on link elevation angles ◦ Skydome correlation data for site-diversity handover timing ◦ Integration with OGS control systems via web API 	<ul style="list-style-type: none"> ◦ Measured cloud attenuation statistics for availability modeling ◦ Measured turbulence parameters (r_0, isoplanatic angle) for AO system sizing ◦ Water vapor column measurements for wavelength-dependent absorption modeling ◦ Optical depth measurements for thin-cloud margin estimation
<p>OGS Site Selection & Network Design</p> <p>Designing an optimal OGS network requires long-baseline statistical atmospheric data at candidate sites. The ASIS M1i provides:</p> <ul style="list-style-type: none"> ◦ Continuous cloud cover statistics — annual, seasonal, and diurnal patterns ◦ Clear-sky fraction by elevation angle and azimuth sector ◦ Radiance climatology for site comparison ◦ Integration with Miratlas LaserCom Pathfinder for network optimization modeling 	<p>Defense & Government Applications</p> <p>For classified FSO networks, directed energy systems, and SATCOM optical terminals, the Solmirus/Miratlas solution provides:</p> <ul style="list-style-type: none"> ◦ Ruggedized, all-weather 24/7 autonomous operation ◦ No cloud dependency — IR imaging works in complete darkness ◦ Self-contained embedded computing — no external cloud dependencies required ◦ Exportable data format for integration with tactical systems ◦ Proven deployments with NASA JPL, Defense, and NOAA

WHY SOLMIRUS + MIRATLAS

<p>Pioneer in IR All-Sky</p> <p>Solmirus delivered the world's first infrared all-sky system for 24/7 monitoring. Since 2004, our instruments have set the standard for atmospheric measurement accuracy in science and industry.</p>	<p>NASA JPL Heritage</p> <p>Engaged since 2017 in laser communications R&D supporting NASA Jet Propulsion Laboratory — focused specifically on atmospheric effects impacting optical communication performance.</p>	<p>Only Complete FSO Solution</p> <p>The Solmirus + Miratlas integrated solution is the only product on the market covering essential CCSDS-recommended atmospheric parameters for FSO from a single deployment.</p>
<p>Trusted Globally</p> <p>Deployed at NOAA, PNNL, ARM, Vera Rubin/LSST, IITM, USAF, Southern Cross University, K-CARE, TROPOS, and more. Backed by hands-on support and deep application expertise.</p>	<p>Miratlas: CCSDS Compliant</p> <p>Miratlas is the first and only provider of a system including all instruments recommended by the CCSDS for FSO Communications — clients include ESA, CNES, DLR, Airbus, NASA, Honeywell, and Orange.</p>	<p>Measurement-Grade Data</p> <p>Both instruments are designed for calibrated, measurement-grade output — not observational estimates. Blackbody-referenced radiance calibration ensures data quality sufficient for link budget and site selection work.</p>

LAMARCK: THE WORLD'S LEADING ATMOSPHERIC DATASET FOR FSO

Lamarck is Miratlas's groundbreaking open atmospheric dataset, designed to accelerate research and innovation in Free Space Optical (FSO) communication and quantum communication systems. Released under the Creative Commons BY-NC-SA 4.0 license, Lamarck provides unprecedented access to high-resolution atmospheric data — including turbulence, cloud cover, humidity, and sky radiance — collected from a global network of over 50 Sky Monitor sites across 17 countries with more coming online soon.

With 19TB of historical data and growing by 1TB per month, Lamarck is the largest and most comprehensive dataset for studying atmospheric effects on FSO and laser communication systems. It empowers researchers, academic institutions, and commercial operators to optimize FSO systems, simulate real-world scenarios, and develop adaptive solutions for satellite-to-Earth and terrestrial laser communication.

Value Proposition for Research Customers

1. Unlimited Access to High-Resolution Atmospheric Data

Lamarck provides academic and research customers with complete, non-commercial access to Miratlas's extensive atmospheric dataset. This includes:

- Turbulence measurements (Fried coherence length, isoplanatic angle, C_n^2 profiles)
- Cloud cover and sky radiance (visible and thermal imaging)
- Humidity, temperature, and weather data
- Historical and real-time data for modeling and analysis

Researchers can use this data to:

- Analyze atmospheric conditions critical for FSO and quantum communication systems
- Simulate real-world scenarios for satellite-to-Earth and terrestrial laser communication
- Develop adaptive optics and encoding algorithms to mitigate signal interference and improve link reliability

2. Creative Commons Licensing for Ethical Use

Lamarck's dataset is released under the CC BY-NC-SA 4.0 license, allowing researchers to:

- Use, share, and adapt the data for non-commercial purposes
- Collaborate and build on existing research while ensuring proper attribution
- Modify and redistribute the dataset, provided it remains non-commercial and adheres to the license terms

This licensing model ensures flexibility for academic studies while maintaining ethical standards and protecting intellectual property.

3. Focus on Free Space Optical Communication Research

Lamarck is tailored to support FSO research, enabling scientists to:

- Study atmospheric interference on laser signals
- Develop turbulence mitigation strategies, such as adaptive optics and advanced encoding algorithms
- Simulate link budgets based on real-world atmospheric conditions
- Explore site diversity and network routing for improved FSO reliability

4. Robust Data Security and Compliance

Miratlas ensures that all data is protected under strict confidentiality and cybersecurity protocols, aligned with GDPR standards. Researchers can trust in the integrity and ethical handling of the data, making it ideal for sensitive and high-stakes academic projects.

5. A Game-Changer for Academic Innovation

By providing unprecedented access to atmospheric data, Lamarck empowers academic teams to:

- Accelerate breakthroughs in FSO and quantum communication technologies
- Collaborate with industry leaders like TU Delft, DLR, and University of North Dakota
- Democratize scientific research by making critical data accessible to institutions worldwide

How to Access Lamarck for Research: Researchers can request access to the Lamarck dataset by contacting Miratlas and signing the Lamarck End User License Agreement. Simply send a message expressing interest, and the team will provide quick and easy access to the platform.

Value Proposition for Commercial Operators

1. Comprehensive Data for FSO Optimization

For commercial operators, Lamarck offers a Data as a Service (DaaS) model, providing real-time and historical atmospheric data to optimize FSO operations. Commercial customers benefit from:

- Real-time monitoring of cloud cover, turbulence, and atmospheric absorption
- Predictive analytics for link scheduling, site diversity management, and adaptive optics
- Global site comparison to identify optimal locations for ground stations

2. Hybrid Subscription Model

Lamarck's DaaS model is structured to meet the needs of commercial operators with a hybrid subscription approach:

- **Core Subscription (Per Site):** Includes real-time data on cloud cover, turbulence, sky radiance, and weather metrics. Basic analytics, API access, and data export capabilities.
- **Add-On Modules (Per Site):**

Add-On	Description
Advanced AI Analytics	AI-driven predictive models for cloud cover and turbulence forecasting.
SHABAR Turbulence Profiling	Daytime Cn ² profiling for adaptive optics and link budgeting.
Thermal Imaging	All-sky thermal data (8–14 μm) for 24/7 cloud cover monitoring.
Historical Data Access	5+ years of historical data for backtesting and model training.
Priority SLA	99.9% uptime guarantee and priority support.
Custom Integration	Dedicated engineering support for integration into customer systems.

3. Global Network for Site Diversity

Lamarck's global network of Sky Monitors provides commercial operators with:

- Site diversity data for network design and redundancy planning
- Cross-site data correlation for improved link reliability and handover efficiency
- Access to a multi-cloud architecture for secure data storage, backhauling, and backup

4. Seamless Integration and AI-Driven Insights

Lamarck's API-first design ensures easy integration with existing OGS control systems and network management tools. Commercial operators can:

- Automate FSO operations with real-time data feeds and customizable alerts
- Optimize link availability using AI-driven predictive analytics
- Improve site selection with data-driven insights and historical trends

5. Compliance and Data Security

Miratlas ensures that all data is protected under GDPR-compliant cybersecurity protocols, giving commercial operators confidence in data integrity and ethical handling.

For Researchers: Lamarck provides unmatched access to atmospheric data under a flexible, non-commercial license, enabling groundbreaking advancements in FSO and quantum communication research. For Commercial Operators: Lamarck's DaaS model offers a scalable, cost-effective solution for optimizing FSO networks, with real-time data, predictive analytics, and global site diversity.

CONTACT & ORDERING

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