2026 Workshop: Meteoroids and Space Debris

Long title
Meteoroids and Space Debris
Conveners
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Description

As meteoroids enter Earth’s atmosphere, their kinetic energy is rapidly converted into heat and ionization, generating transient plasmas that form meteor trails. Despite more than a century of study, fundamental questions remain regarding meteoroid ablation, plasma instabilities, fragmentation processes, metal layer formation, and ionospheric coupling.

In parallel, the rapid growth of anthropogenic orbital debris has introduced a new population of artificial meteoroids re-entering the atmosphere. These objects pose increasing risks to satellite infrastructure and contribute additional material and plasma processes to the upper atmosphere. Understanding the physical, chemical, and electrodynamic interactions of both natural and artificial particles is essential for space sustainability and atmospheric science.

This session invites contributions addressing the physics and engineering of meteoroids, meteor plasmas, and space debris, including their impact on the neutral atmosphere, ionosphere, and space-based systems. Topics of interest include, but are not limited to:

• Meteoroid ablation, ionization, and fragmentation dynamics
• Plasma instabilities and trail evolution (underdense, overdense, and non-specular echoes)
• Coupling to sporadic E layers and metal chemistry
• Space debris re-entry physics and atmospheric interactions
• Implications for satellite operations and space situational awareness
• Multi-instrument observations: radar (monostatic/multistatic), lidar, optical, infrasound, and satellite-based measurements
• Development of low-cost radar systems and distributed sensor networks
• Data assimilation and modeling approaches

• Applications of artificial intelligence and machine learning for detection, classification, and physical inference

Recent investments in multistatic radar networks, regional meteor systems, and optical monitoring arrays are enabling unprecedented coordinated observations. Emerging AI-driven analysis methods are further transforming the field, allowing automated classification of meteor echoes, fragmentation detection, debris characterization, and large-scale statistical studies.

We particularly encourage interdisciplinary contributions bridging atmospheric physics, plasma science, radar engineering, space situational awareness, and computational data science.

Agenda

This is the zoom link for online participation:

https://psu.zoom.us/j/3712177659

The times listed below are approximate.

10:00 – 10:10 AM

Millions of Meteors Hit the Earth Each Second: What Happens, Why it Matters, and What are the Outstanding Questions

Meers Oppenheim[1]

Affiliation:

[1] Department of Astronomy and Center for Space Physics, Boston University, USA

10:10 – 10:25 AM

From Micrometeors to Fireballs: Modeling Coupled Neutral and Plasma Flows

Alex Green[1], *Meers Oppenheim*[1]

Affiliation:

[1] Department of Astronomy, Boston University, USA

10:25 – 10:35 AM

Preliminary Results from Radar Observations of the 30 May 2026 Cape Cod Bay Bolide

Juha Vierinen[1], Ryan Volz[2], Jorge L. Chau[3], Philip J. Erickson[4], Marc Fries[5]

Affiliations:
[1] The Arctic University of Norway (UiT), Tromsø, Norway
[2] University of Alaska Fairbanks, USA
[3] Leibniz Institute of Atmospheric Physics, Germany
[4] MIT Haystack Observatory, USA
[5] NASA Johnson Space Center, USA

10:35 – 10:45 AM

Observations of Plasma Irregularity Trails Produced by an Uncontrolled Falcon 9 Re-entry Using a Multistatic Meteor Radar over Northern Germany
Jorge L. Chau[1], Juha P. Vierinen[2,1], Matthias Clahsen[1], Devin Huyghebaert[1], Dabroka Knach[2], Toralf Renkwitz[1]

Affiliations:
[1] Leibniz Institute of Atmospheric Physics at the University of Rostock, Kühlungsborn, Germany
[2] Department of Physics and Technology, UiT The Arctic University of Norway, Tromsø, Norway

10:45 – 11:05 AM

Detection and Tracking of Low-Inclination Space Debris Passing Through Equatorial Ionospheric Irregularities
Paul A. Bernhardt[1], Bengt Eliasson[2], Andrew Howarth[3], Robert Marshall[4], Charles Swenson[5], Joe Huba[6]

Affiliations:
[1] Geophysical Institute, University of Alaska Fairbanks, USA
[2] Department of Physics, University of Strathclyde, Glasgow, UK
[3] University of Calgary, Calgary, AB, Canada
[4] University of Colorado Boulder, USA
[5] Utah State University, USA
[6] Syntek Technologies, Fairfax, VA, USA

11:05 – 11:15 AM

Searching for Ionospheric Signatures of the May 30, 2026 Cape Cod Bay Meteor Explosion

Enrique Rojas[1], Larisa Goncharenko[1], Shun-Rong Zhang[1], Nestor Aponte[1], Anthea Coster[1]

Affiliation:

[1] MIT Haystack Observatory, Westford, MA, USA

11:15 – 11:25 AM

Expanding Meteor Observation Capabilities with Machine Learning

Nicholas Holl[1], Julio Urbina[1], Yanlin Li[1], Frederick Galindo[1], Pedrina Terra dos Santos[2]

Affiliations:

[1] The Pennsylvania State University, USA

[2] Florida Space Institute, University of Central Florida, USA

11:25 – 11:35 AM

An Alternative to Interferometry: Developing a Time-of-Flight Position Solution for Specular Meteor Radar Networks

James Monaco[1], Scott Palo[1], Kenneth Obenberger[2]

Affiliations:

[1] Aerospace Engineering Sciences, University of Colorado Boulder, USA

[2] Air Force Research Laboratory, USA

11:35 – 11:45 AM

Status and Early Results of the SIMONe Haystack Meteor Radar Network

Ryan Volz[1], Dupinder Singh[1], Philip Erickson[1], Larisa Goncharenko[1], Jorge Chau[2], Matthias Clahsen[2], Nico Pfeffer[2]

Affiliations:

[1] MIT Haystack Observatory, USA

[2] Leibniz Institute of Atmospheric Physics, Germany

11:45 – 11:55 AM

The CONDOR Multi-Static Meteor Radar Network: Current Status, Expansion, and New Science Opportunities

Alan Liu[1], Marie Bals[1], Jorge Chau[2], J. Federico Conte[2], Gunter Stober[3], Chris Adami[4], Carlos Segura[5]

Affiliations:
[1] Embry-Riddle Aeronautical University
[2] Leibniz Institute of Atmospheric Physics
[3] University of Bern
[4] ATRAD Pty Ltd.
[5] AURA NOIRLab, Cerro Pachón

11:55 AM – 12:00 PM

Primas Meteor Radar at Culebra, Puerto Rico: Current Status
Pedrina Terra dos Santos et al.

Affiliation:
Florida Space Institute, University of Central Florida, USA

12:00 PM

Adjourn

Justification

Viewing the Earth–atmosphere–geospace system as an interconnected and dynamically coupled environment, meteoroids and re-entering orbital debris represent a continuous source of mass, momentum, energy, and ionization to the upper atmosphere. These particles influence atmospheric chemistry, metal layer formation, ionospheric structure, plasma instabilities, and electrodynamic coupling processes across a wide range of spatial and temporal scales. Natural meteors and artificial debris alike now play a measurable role in space sustainability, satellite risk assessment, and the long-term evolution of near-Earth space.
Despite more than a century of investigation, fundamental questions remain unresolved. These include the physical scattering mechanisms responsible for radar head echoes, the role of fragmentation in trail evolution, the formation and structuring of sporadic E layers, the accurate quantification of meteoric mass input into the atmosphere, and the plasma processes governing underdense, overdense, and non-specular echoes. For anthropogenic debris, uncertainties remain regarding re-entry plasma dynamics, ablation chemistry, and their cumulative impact on the upper atmosphere.

Addressing these challenges requires coordinated and modernized approaches. Emerging multistatic radar networks, distributed low-cost sensor arrays, optical systems, lidar, infrasound observations, and satellite-based platforms are enabling multi-instrument, multi-scale investigations. Advances in computational plasma modeling, data assimilation frameworks, and artificial intelligence and machine learning techniques now permit automated echo classification, fragmentation detection, debris characterization, and large-scale statistical inference across massive datasets. Interdisciplinary collaboration between plasma physicists, atmospheric scientists, radar engineers, and space situational awareness experts is essential.

Progress in this field should be measured by (1) improved physical consistency between observations and first-principles models, (2) reduction in uncertainty in meteoric and debris mass flux estimates, (3) successful integration of multi-instrument datasets, (4) operational advances in detection and classification using AI-driven methodologies, and (5) demonstrable contributions to satellite risk mitigation and space sustainability frameworks. Training of students and early-career researchers through the development of accessible radar systems and open data methodologies should also be considered a key metric of long-term impact.

Related to CEDAR Science Thrusts:

Explore processes related to geospace evolution

Develop observational and instrumentation strategies for geospace system studies

Workshop format

Short Presentations

Keywords

meteor radar, optical, satellite, modelling, space debris

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