Key components of the Next Generation Solar Physics Mission (NGSPM)

- **MUSE** and **EUVST** align with NASA/ESA/JAXA NSGPM report call for simultaneous observations of the whole solar atmosphere from:

0.3- 0.4" coronal / TR spectrograph	0.2" - 0.6" coronal imager	0.1" - 0.3" photospheric/chromospheric spectropolarimeter
Solar-C_EUVST, MUSE	MUSE	DKIST + **Other Ground-based Observatories**

- **NGSPM** = **EUVST** x **MUSE** x **DKIST**

Complete Temperature Coverage x **Complete Spatio-temporal coverage** x **Magnetic Field Coverage**

- **MUSE x EUVST x DKIST** (and other GBOs) will address science goals of NGSPM: coronal heating, drivers of space weather & solar wind
  - See De Pontieu et al., ApJ, 926, 52, 2022, doi:10.3847/1538-4357/ac4222 ; Cheung et al., 2022, ApJ, 926, 53, doi:10.3847/1538-4357/ac4223
- **MUSE** science investigation is committed to NGSPM science objectives:
  - Includes **EUVST** (and DKIST) Co-I's for optimal alignment of science priorities and operations
  - Prioritizes coordinated observations with **EUVST**

MUSE and EUVST are highly complementary [1/2]

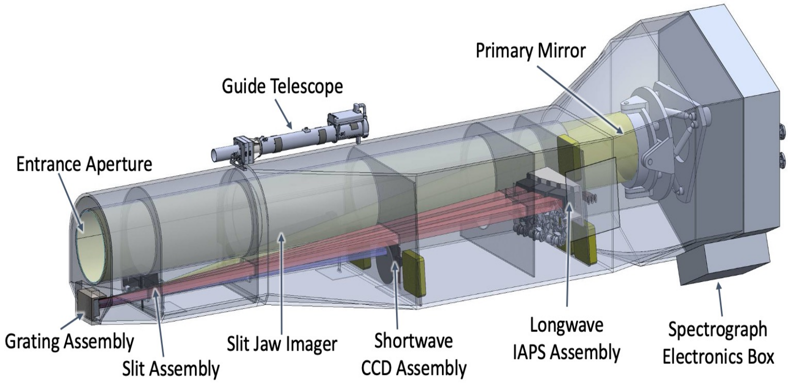
- Both are revolutionary high-resolution spectrographs focusing on different aspects, but are highly complementary:
  - **EUVST**: single slit spectrograph w/ broad temperature coverage and rich diagnostics (density, abundances); low-atmospheric context imaging (photosphere, chromosphere)
    - LRD: NET Sep 2027
  - **MUSE**: multi-slit spectrograph w/ narrow temperature coverage at 40x higher cadence over large field-of-view, coronal context imaging
    - LRD: NET Feb 2027

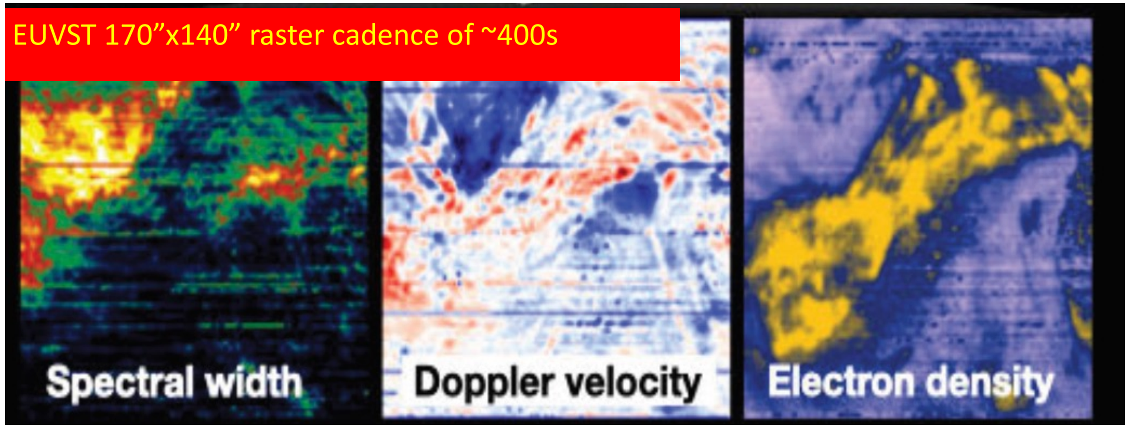
Instrument	Resolution	Spectroscopy:			Imaging	Avg. Downlink Datarate
		Temperature	Cadence	FOV		
EUVST	0.4"	0.01–15 MK with ~20 lines	12s (AR)	3″ x 140″	Photosphere & chromosphere over 300″x300″	0.7 Mbit/s
MUSE	0.33-0.4"	0.7 – 11 MK with 4 lines	12s (AR)	170″x170″	TR & corona over 580″x580″	21.4 Mbit/s

- **MUSE x EUVST** for the first time capture the multi-scale nature of the physical processes in the corona, where energy is released on small scales (~0.5″) but rapidly impacts large scales (~100″, AR-size), across a wide range of temperatures, in coronal loops, flares, & coronal mass ejections

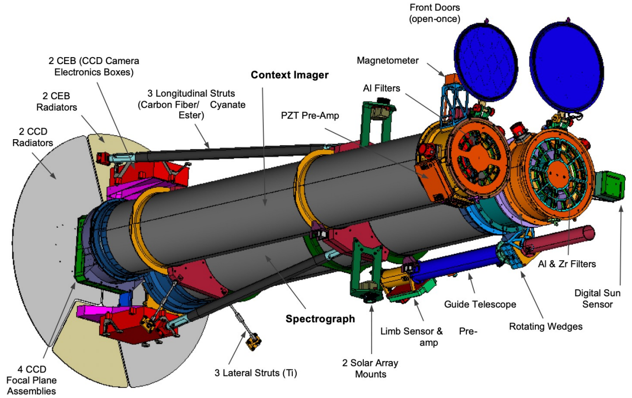
MUSE and EUVST are highly complementary [2/2]

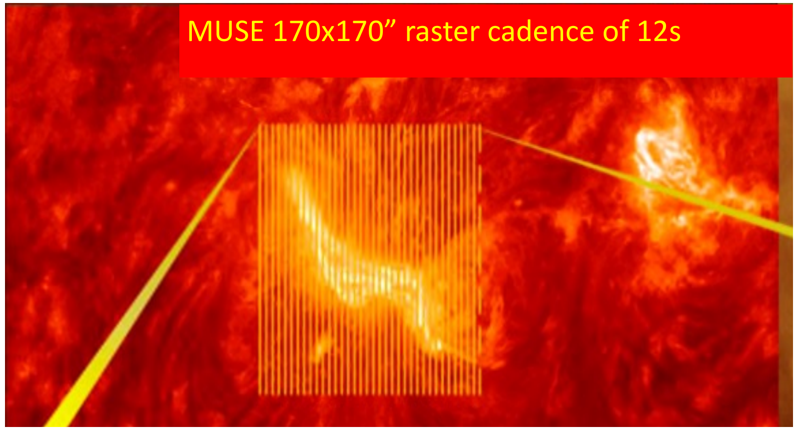
EUVST





MUSE





MUSE x EUVST capture multi-scale processes involved in coronal heating and flares/eruptions

MUlti-slit Solar Explorer Overview

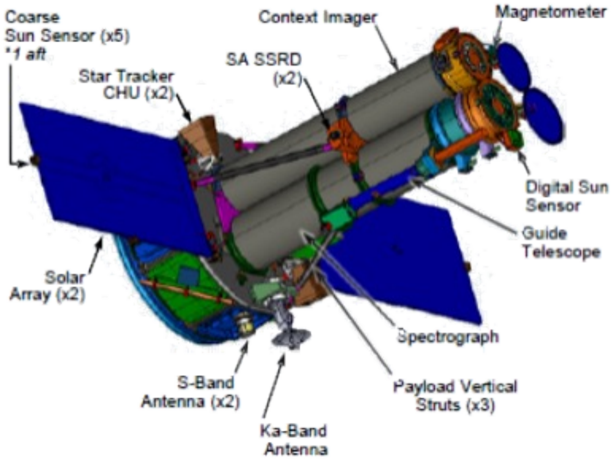
Mission Overview

MUSE will obtain EUV spectra and images with highest resolution in space (0.33-0.4 arcsec) and time (1-4 s) for transition region and corona, along 37 slits (using innovative grating in Spectrograph) with a large context FOV from Context Imager. MUSE's 37 slits provide a 100x improvement in spectral raster cadence to: freeze plasma evolution in flares, CMEs, & corona for first time with a spectrograph, and to reveal processes that remain invisible to current and planned instruments.

EOM disposal: No propulsion, Natural decay results in re-entry within 25 years of end of mission.

Science Objectives

1. Determine which mechanism(s) heat the corona and drive the solar wind
2. Understand the origin and evolution of the unstable solar atmosphere
3. Investigate fundamental physical processes in the corona



Key Mission Requirements

Mission Design Life	2-year prime mission mission
Orbit	Low-earth Sun-synchronous orbit (620 km)
Mass (predicted)	225.7 kg MEV total; Instrument: 113.0 kg MEV, S/C Bus:112.7 kg MEV
Power	28V, 423W at EOL, 31% margin

Programmatics

- Project Category 3 / Risk Class C
- Launch Readiness Date: NET Feb 2027*
- PI Cost Cap: $192M
- Mission Kickoff Meeting: Mar 24, 2022

SRR	Q1 2023*
PDR	Q1 2024*
CDR	Q4 2024*

MOR	Q3 2025*
SIR	Q4 2025*
PSR	Q3/4 2026*

*Current best dates available, but subject to change as mission matures, all dates in CY

Project Organization

- Principal Investigator: Bart De Pontieu, Lockheed Martin Advanced Technology Center (LM ATC)
- Project Manager: Gary Kushner, LM ATC
- Mission Manager: Roberto Aleman, NASA GSFC/Explorers Program Office
- Program Executive: Heather Futrell, NASA HQ/SMD/Heliophysics
- Program Scientist: Lika Guhathakurta, NASA HQ/SMD/Heliophysics

Mission Architecture Teams

- Payload (Spectrograph and Context Imager), Systems I&T, Data Processing, Science Operations and Analysis: LM ATC
- Spacecraft Systems I&T: LM Commercial Civil Space
- Science analysis: SAO & GSFC
- Science Pipeline: LATC, UCB, KSAT & NSN
- Student Collaboration: Montana State University

MUSE x EUVST x DKIST synergy described in 2 ApJ papers

The Astrophysical Journal, 00:000000 (36pp), 2021 Month Day

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Probing the Physics of the Solar Atmosphere with the Multi-slit Solar Explorer (MUSE). I. Coronal Heating

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Abstract

The Multi-slit Solar Explorer (MUSE) is a proposed mission composed of a multislit EUV spectrograph (in three spectral bands around 171 Å, 284 Å, and 108 Å) and an extreme ultraviolet (EUV) context imager (in two passbands around 195 Å and 304 Å). MUSE will provide unprecedented spectral and imaging diagnostics of the solar corona at high spatial ($\leqslant 0\farcs5$) and temporal resolution (down to ~0.5 s for sit-and-stare observations), thanks to its innovative multislit design. By obtaining spectra in four bright EUV lines (Fe IX 171 Å, Fe XV 284 Å, Fe XIX–Fe XXI 108 Å) covering a wide range of TR and coronal temperatures along 37 slits simultaneously, MUSE will, for the first time, "freeze" (at a cadence as short as 10 s) with a spectroscopic raster the evolution of the dynamic coronal plasma over a wide range of scales: from the spatial scales on which energy is released ($\leqslant 0\farcs5$) to the large-scale (~170″ × 170″) atmospheric response. We use numerical modeling to showcase how MUSE will constrain the properties of the solar atmosphere on spatiotemporal scales ($\leqslant 0\farcs5$, $\leqslant$20 s) and the large field of view on which state-of-the-art models of the physical processes that drive coronal heating, flares, and coronal mass ejections (CMEs) make distinguishing and testable predictions. We describe the synergy between MUSE, the single-slit, high-resolution Solar-C EUVST spectrograph, and ground-based observatories (DKIST and others), and the critical role MUSE plays because of the multiscale nature of the physical processes involved. In this first paper, we focus on coronal heating mechanisms. An accompanying paper focuses on flares and CMEs.

Unified Astronomy Thesaurus concepts: Solar coronal heating (1989); Theoretical models (2107); Solar instruments (1499);

Supporting material: animations

The Astrophysical Journal, 00:000000 (33pp), 2021 Month Day

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Q1 Q2

Probing the Physics of the Solar Atmosphere with the Multislit Solar Explorer (MUSE). II. Flares and Eruptions

Q3 Q4 Q5

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Abstract

Current state-of-the-art spectrographs cannot resolve the fundamental spatial (subarcseconds) and temporal (less than a few tens of seconds) scales of the coronal dynamics of solar flares and eruptive phenomena. The highest resolution coronal data to date are based on imaging, which is blind to many of the processes that drive coronal energetics and dynamics. As shown by τηε Interface Region Imaging Spectrograph for the low solar atmosphere, we need high-resolution spectroscopic measurements with simultaneous imaging to understand the dominant processes. In this paper: (1) we introduce the Multislit Solar Explorer (MUSE), a spaceborne observatory to fill this observational gap by providing high-cadence (<20 s), subarcsecond-resolution spectroscopic rasters over an active region size of the solar transition region and corona; (2) using advanced numerical models, we demonstrate the unique diagnostic capabilities of MUSE for exploring the solar coronal dynamics and for constraining and discriminating models of solar flares and eruptions; (3) we discuss the key contributions MUSE would make in addressing the science objectives of the Next Generation Solar Physics Mission (NGSPM), and how MUSE, the high-throughput Extreme Ultraviolet Solar Telescope, and the Daniel K Inouye Solar Telescope (and other ground-based observatories) can operate as a distributed implementation of the NGSPM. This is a companion paper to De Pontieu et al., which focuses on investigating coronal heating with MUSE.

Unified Astronomy Thesaurus concepts: Active solar corona (1988); Solar coronal mass ejections (310); Solar coronal waves (1995); Solar flares (1496); Extreme ultraviolet astronomy (2170); Solar extreme ultraviolet emission (1493); Magnetohydrodynamics (1964); Radiative magnetohydrodynamics (2009); Astrophysical fluid dynamics (101); Solar instruments (1499); Astronomical instrumentation (799)

Supporting material: animations

Acronyms

ATC	Advanced Technology Center
CDR	Critical Design Review
CI	Context Imager
CME	Coronal Mass Ejection
CY	Calendar Year
DKIST	Daniel K. Inouye Solar Telescope
EOL	End of Life
EOM	End of Mission
EUV	extreme ultraviolet
EUVST	Extreme Ultraviolet High-Throughput Spectroscopic Telescope
FOV	Field of View
GBOs	Ground Based Observatories
GSFC	Goddard Space Flight Center
HQ	Headquarters
I&T	Integration and Test
KSAT	Kongsberg Satellite Services
LM	Lockheed Martin
MEV	Maximum Expected Value
MOR	Mission Operations Review
MUSE	MUlti-slit Solar Explorer

NGSPM	Next Generation Solar Physics Mission
NSN	Near Space Network
PDR	Preliminary Design Review
PI	Principal Investigator
PSR	Pre-Ship Review
SAO	Smithsonian Astrophysical Observatory
SIR	System Integration Review
SMD	Science Mission Directorate
SRR	Systems Requirements Review
UCB	University of California, Berkeley