TRACERS

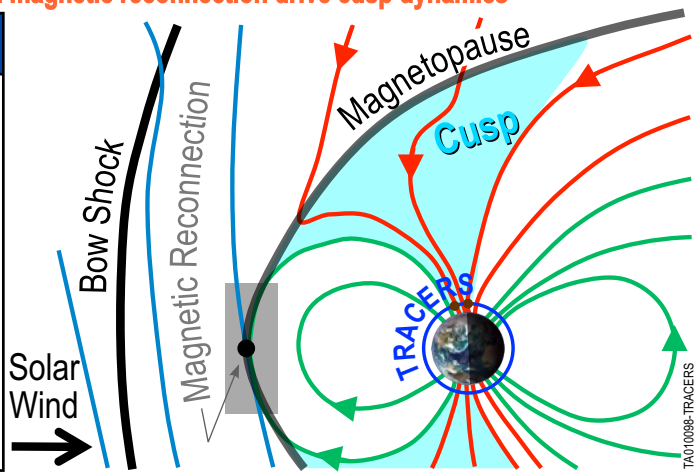
Tandem Reconnection & Cusp Electrodynamics Reconnaissance Satellites

Overarching Goal: Connecting the cusp to the magnetosphere – discovering how spatial or temporal variations in magnetic reconnection drive cusp dynamics

SO	TRACERS Science Objective (SO's)
SO1	Determine whether magnetopause reconnection is primarily spatially or temporally variable for a range of solar wind conditions.
SO2	For temporally varying reconnection, determine how the reconnection rate evolves.
SO3	Determine to what extent dynamic structures in the cusp are associated with temporal versus spatial reconnection.

Mission Highlights

- Two spacecraft observations in the cusp distinguish temporal versus spatial reconnection variability.
- Identical 510 km altitude, sun-synchronous orbits with spacecraft separated by 10 s to 2 min.
- Identical, high-heritage spacecraft and instruments make identical measurements of plasma and fields in the cusp.
- 6500 cusp crossings in the 2-year mission determine reconnection variability over a wide range of solar wind conditions.
- Simple mission operations and proven analysis techniques backed by high-fidelity simulations enables TRACERS science objectives.

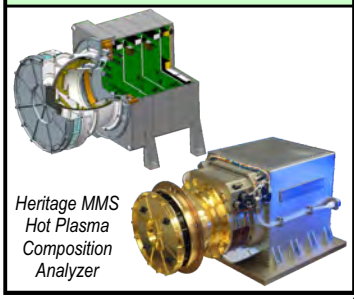


Importance of TRACERS to the NASA Heliophysics Science Goals

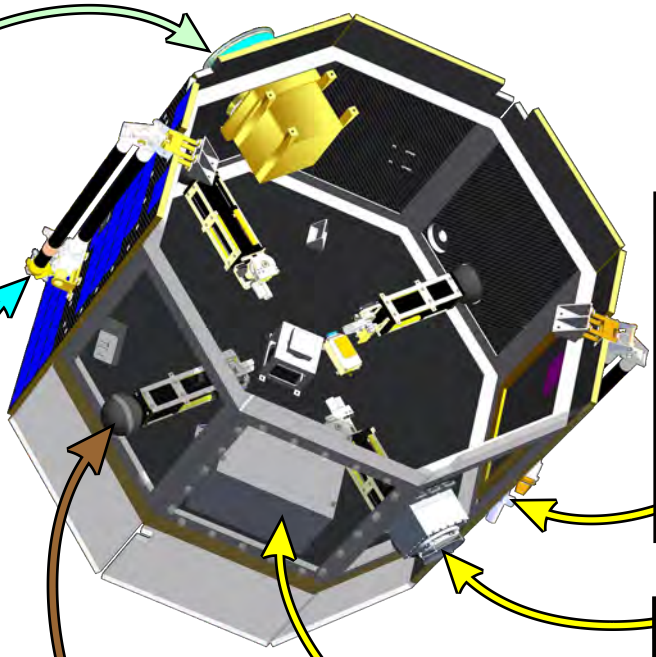
TRACERS overarching science goal is directly aligned with two heliophysics Decadal Survey Critical Science Goals: ***Understanding Fundamental Processes and Dynamics*** and ***Coupling of the Earth's Magnetosphere***. Understanding the modulation of reconnection is a critical element in understanding this fundamental process. TRACERS also aligns with top-level objectives and research focus areas in: ***Our Dynamic Space Environment: Heliophysics Science and Technology Roadmap for 2014-2033. Specifically: Solve the Fundamental Mysteries of Heliophysics (F) - Understand magnetic reconnection (F1), Understand the plasma processes that accelerate and transport particles (F2) and Understand the Nature of Our Home Planet (H), Understand the coupling of the Earth's magnetosphere-ionosphere-atmosphere system, and its response to external and internal forcing (H3).***

TRACERS Satellite (both [T1 & T2] identical) comprised of Spacecraft [S/C] Bus & Instrument Suite)

Analyzer for Cusp Ions

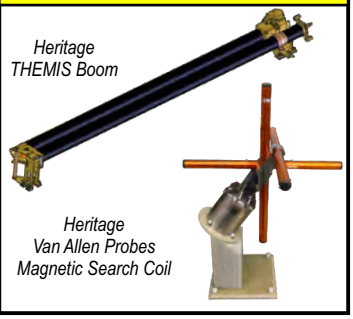


Heritage MMS Hot Plasma Composition Analyzer



Electric Field Instrument, Magnetic Search Coil, and Magnetometer shown in stowed configuration. (Spacecraft components removed to emphasize instruments)

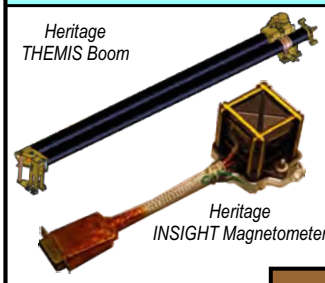
Magnetic Search Coil



Heritage THEMIS Boom

Heritage Van Allen Probes Magnetic Search Coil

Magnetometer



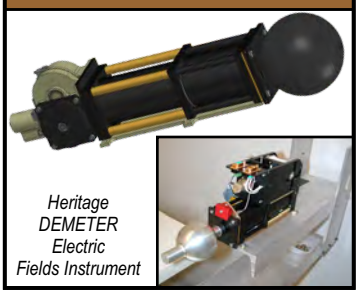
Heritage THEMIS Boom

Heritage INSIGHT Magnetometer

Analyzer for Cusp Electrons

Heritage ACES & CHARM-2

Electric Field Instrument



Heritage DEMETER Electric Fields Instrument

Main Electronics Box

Heritage Van Allen Probes

Legend

- SwRI
- UCLA
- Iowa
- UCB

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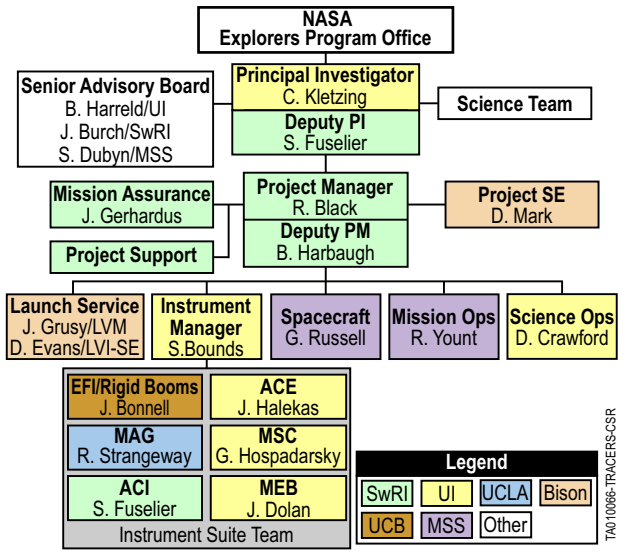
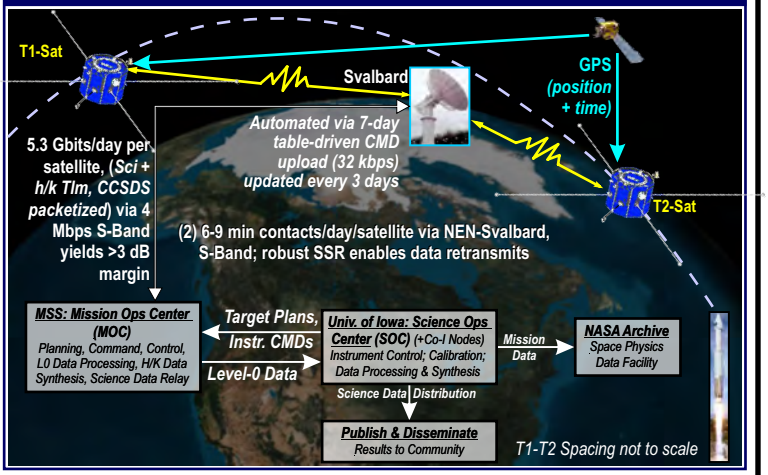
Mission Management and Participating Organizations

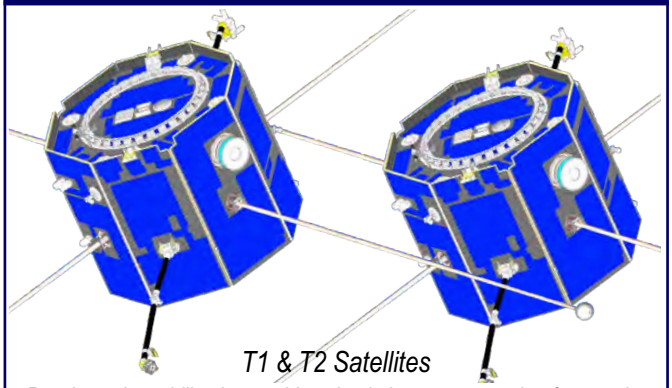


- Principal Investigator (UI) has >30 years experience developing and operating spaceflight instruments, both fields & particles; PI/Co-I on several NASA missions
- Deputy PI (SwRI) is lead Co-I for MMS-HPCA; Co-I on TRICE-2 sounding rockets, IMAGE, IBEX
- Project Manager (SwRI) has >30 years instrument development and space hardware management experience; managed the MMS payload team
- PSE (Bison) has over 30 years of successful PM & SE experience on PI-led cost- and schedule-capped missions & instruments (e.g., EUVE, VA Probes, THEMIS, FUSE)
- Instrument Providers (UC Berkeley, UCLA, SwRI, UI) have extensive experience designing and developing successful space instrumentation on multiple missions MMS,IMAGE, IBEX together
- MSS has S/C development experience with RPP, WFOV, ALTAIR Pathfinder
- MSS MOC builds on 6 years on-orbit operations experience starting with RPP
- MSS staff experienced in development & operations on 46 satellite programs
- Science Operations Center (UI) builds on successful VA Probes SOC for integration with MOC and seamless support during I&T, commissioning, & operations

Mission Profile



Key Satellite Characteristics



T1 & T2 Satellites

- Passive spin stabilization enables simple instrument modes & operations
- Power, RF, and thermal-positive in all attitudes
- Spacecraft bus design uses strong WFOV/ALTAIR heritage and leverages legacy industry components for Low Earth Orbit
- Balanced hydrazine system heritage components and Millennium's in-house fabrication control schedule
- Booms have direct THEMIS heritage

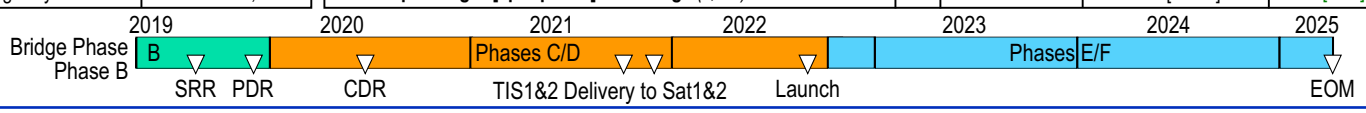
Launch Operations

- 8/31/2022 Launch Readiness benefits Science Enhancement Option ground asset return
- **TRACERS can launch any day of the year** & uses modest 400 kg T1/T2 total agreed-to wet mass to orbit
- T0 umbilical control and GN2 purging simplify launch processing
- Adaptive Launch Solutions co-manifest launch service supports LRD, injection ops and VAFB launch

Strong Technical and Programmatic Resource Margins

Key Mission Milestones	
SRR	July 18, 2019
Mission PDR	November 14, 2019
Mission CDR	June 18, 2020
SIR	September 30, 2021
FOR/ORR	June 2, 2022
PSR	June 16, 2022
Launch	August 31, 2022
Flight System EOM	November 30, 2024

Satellite Resource (each satellite)	CBE	Contingency	Reqd/Agreed-to Limit	Margin
Mass, *dry (kg): Baseline Co-Manifest*	89	14 (16%)	165	62 (60%)
Power, W_{avg}, *Main Science Modes (worst-case seasonal altitude)*	52.7	8.4 (16%)	85 (EOL)	24 (39%)
Propellant *(kg): Baseline Co-Manifest*	3.7	0.6 (16%) + 0.45 (inaccessible)	35	30.3 (640%)
RF Primary downlink *(4π Sr-omni, 4Mbps)*	>3 dB CBE *(compliant with AO and NASA GOLD rules)*			
Ground Contact *(min/day/sat: 2 passes)*	10.4	n/a	16.7	6.3 (61%)
Position *(orbit)* **determination** *(m, 3σ)*	13.8	n/a	500	486 (2042%)
Satellite pointing control to LABF *(B-field) total end-end errors, 3σ*	3.7°	n/a	≤10°	6.3° (170%)
S/C bus pointing & [spin-phase] knowledge *(°, 3σ)*	0.2°	n/a	±1° [±0.4°]	0.8° [0.2°]



PI-Managed Mission Cost
$165M (FY17$) $185.5M (RY$)

Total Mission Cost: TRACERS has no hardware contributions. Only science contributions = $64K (FY17) total for U Sydney and CAS

Phase B-D Reserves
FY17 $34.7M (30.6%)