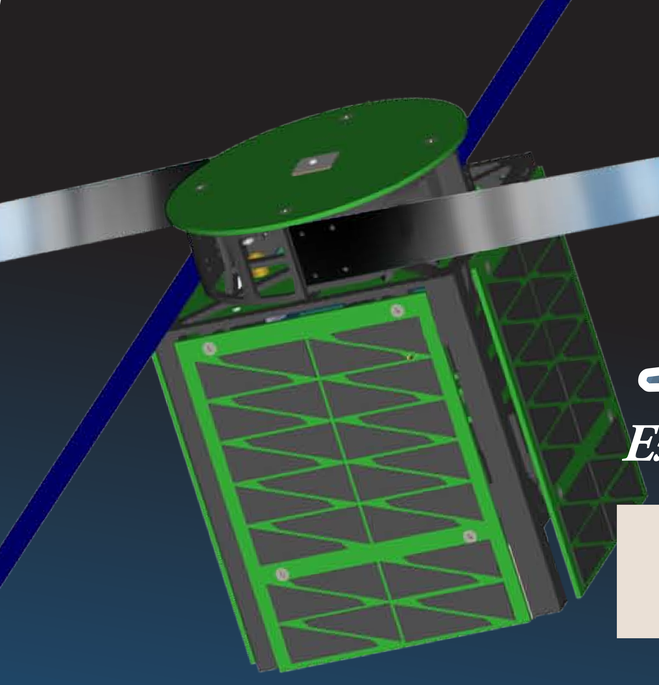


HiDEF

Exploring the Last Major Link in the Sun-Earth Connection

Importance to NASA Science

The HiDEF science questions will provide key information for the Heliophysics Roadmap Focus Areas F3 and H2, enhancing our understanding of the Sun-Earth connection.

Science Objective

The High-latitude Dynamic E-Field (HiDEF) Explorer will observe and resolve the inadequately understood high-latitude magnetosphere-ionosphere-thermosphere global electric field forcing, coupling dynamics, and evolution over a wide range of spatial and temporal scales, providing the last major link in the Sun-Earth connection.

Science Investigation Questions to be Answered

The HiDEF mission science will focus on three principle science questions that help resolve the understanding of the Sun-Earth connection. The first question deals with the electric field structure at the smallest temporal and spatial scales and is primarily associated with Phase 1 of the mission (see Mission Design). The second and third questions deal with the larger scale structures and require the broader global-scale coverage of the high-latitude regions achieved in Phase 2 of the mission.

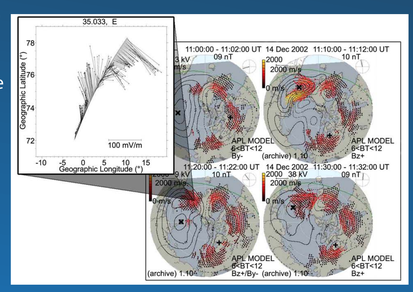
Mission Objective

HiDEF will deploy a large constellation of satellites into LEO to provide continuous global high-latitude measurements of the electric field parameter and fill the gap in the last major link of the Heliophysics Great Observatory chain.

Question 1: What is the contribution of small-scale turbulent electric fields to the larger-scale electrodynamical processes?

Question 2: How do the high-latitude electric fields evolve during disturbed conditions?

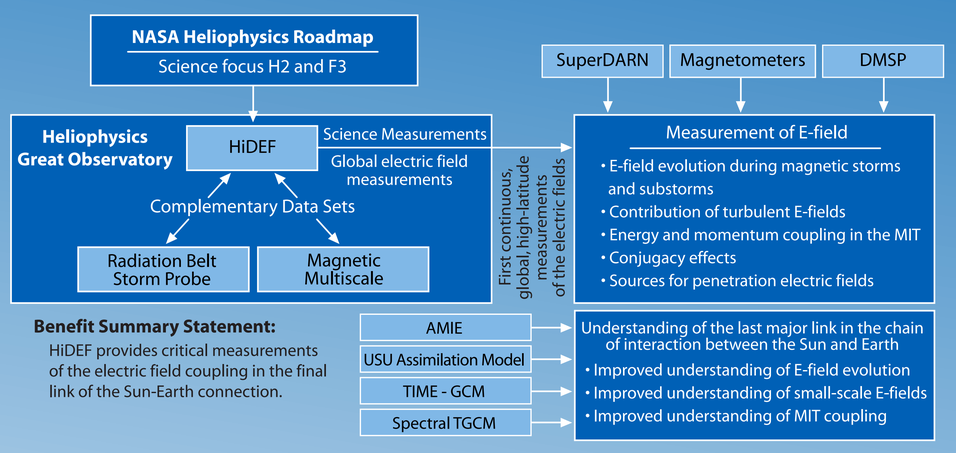
Question 3: What are the high-latitude sources for mid- and low-latitude penetration electric fields?



NASA Heliophysics Roadmap Focus Areas	HiDEF Science Question Information
F3: Understand the role of plasma and neutral interactions in the nonlinear coupling of regions throughout the solar system	Q1 and Q2 will directly provide critical information about the drivers for those nonlinear interaction processes
H2: Determine changes in the Earth's magnetosphere, ionosphere, and upper atmosphere to enable specification, prediction, and mitigation of their effects	Q1, Q2, and Q3 will directly determine the changes in the ionospheric electric fields to enable the specification of their effects.

Mission Management

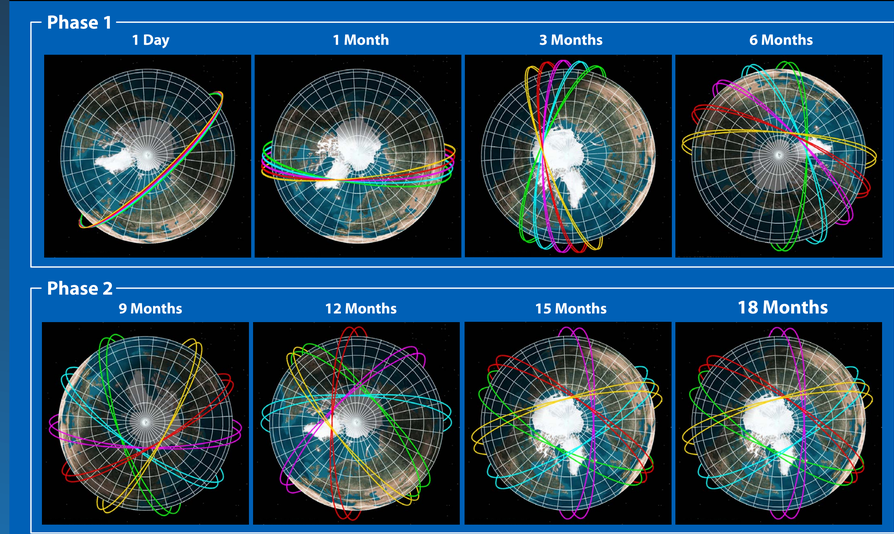
PI	Miguel Larsen (Clemson University)	Science Payload Provider	USU/SDL
Deputy PI	Jan Sojka (Utah State University)	Mission Ops	GATS Inc.
Science Team	Clemson, USU, Cornell, ASTRA, Dartmouth	S-band Ground Systems	USN
Project Management	Lorin Zollinger, USU/SDL	VHF Ground Systems	Stanford
Systems Engineering	USU/SDL	Payload Data Center	USU/SDL
Spacecraft Deployment System	USU/SDL, Cal Poly	Public Data Interface	Clemson University
Spacecraft Provider	USU/SDL	Education & Public Outreach	Clemson University



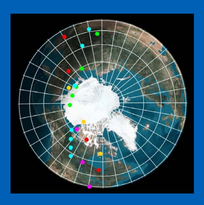
Benefit Summary Statement:
HiDEF provides critical measurements of the electric field coupling in the final link of the Sun-Earth connection.

HiDEF Mission Design

Orbital Dispersion at Selected Times

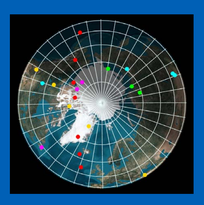


Primary Science Question(s) to be answered:



Phase 1
Dense Cluster

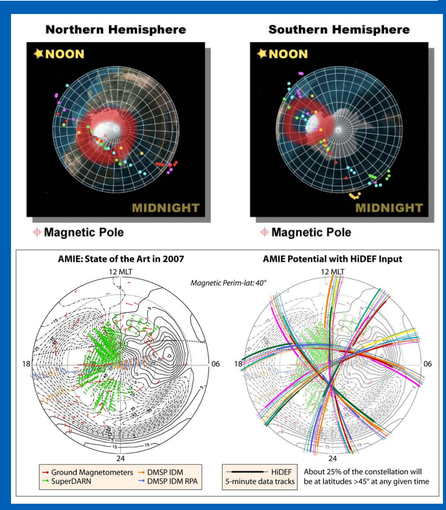
What is the contribution of small-scale turbulent electric fields to the larger-scale electrodynamical processes?



Phase 2
Global Network

How do the high-latitude electric fields evolve during disturbed conditions?

What are the high-latitude sources for mid- and low-latitude penetration electric fields?



Mission Overview

Objective:	Global *in-situ* E-field measurement
Mission Phases:	1 – Packed cluster into string of pearls 2 – Distributed network
Duration:	18 months
Launch Date:	July 2012 targeted, launch date flexible
Disposal:	Via atmospheric drag (<25 years)

Orbital Parameters

Satellite Orbit Group	Release Altitude	Semi-Major Axis	Inclination	RAAN Precession Rate
	km	km	degrees	degrees/day
1	515	6884 – 6902	77.0°	-1.70 to -1.72
2	555	6924 – 6942	77.7°	-1.58 to -1.59
3	595	6964 – 6982	78.4°	-1.46 to -1.47
4	635	7004 – 7022	79.1°	-1.35 to -1.36
5	675	7044 – 7063	79.8°	-1.24 to -1.25

Right Ascension of Ascending Node:	277.5°
True Anomaly:	varies by satellite
Argument of Perigree:	varies by satellite
Eccentricity:	0.0003 to 0.0013

Orbit Lifetime Analysis

Satellite Orbit Group	CBE Lifetime*	Standardized Compliance Lifetime **
	years	years
1	2.4 - 4.0	1.1 to 1.5
2	6.1 - 6.9	2.1 to 2.9
3	7.8 - 8.7	4.1 to 5.6
4	10.8 - 17.1	7.9 to 10.5
5	19.6 - 27.7	14.3 to 18.7

* Based on time varying 4th order cosine fit curve of F10.7 data
** Orbit lifetime compliance analysis for debris mitigation per NSS 1740.14, using DAS 1.5.3. Range represents minimum and maximum lifetime within satellite orbit group.

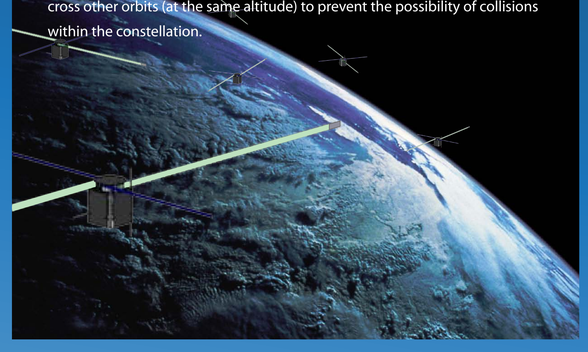
Ground Stations

USN CCSDS S-band
128 bps FSK uplink
128 kbps (effective) QPSK downlink

North Pole, Alaska (dedicated antenna)
Kiruna, Sweden (dedicated antenna)
Mengeneu, Australia (dedicated antenna)
South Point, Hawaii (for LEOP only)
Santiago, Chile (for LEOP only)

Orbit Design Supports Mission

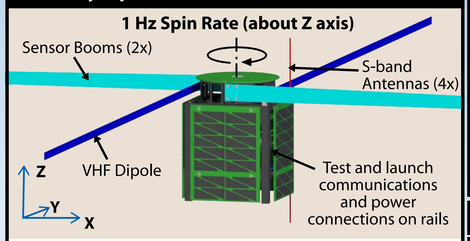
- Orbit insertion designed so that satellites will disperse quickly into a string of pearls and the orbit planes will spread over time for global coverage.
- Orbit insertion is designed so that each satellite orbit is unique and does not cross other orbits (at the same altitude) to prevent the possibility of collisions within the constellation.



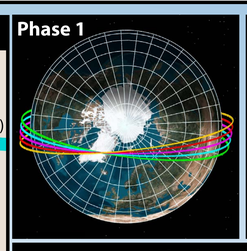
Mission Characteristics

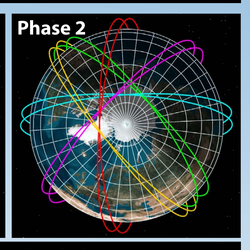
Constellation Size	90 satellites (20% design redundancy)	Science Payload	Electric Field Sensor
Orbit Altitudes	515-675 km	Daily Data Volume	619 Mbytes total from 90 satellites
Orbit Inclinations	77-79.8 °	Comm Link	S-band (CCSDS)
Constellation Lifetime	up to 19 years	Backup Tracking	VHF beacon
Mission Lifetime	≥ 18 months (2 weeks of LEOP)	Constellation Timing	≤ 1 second absolute synchronization
Mission Phases	Phase 1 (Cluster): 0-6 months Phase 2 (Global network): 6-18 months	Ground System	3 Dedicated USN sites

Key Spacecraft Characteristics



Basic Design	Deployable sensor and communication booms, Body-mounted solar arrays, Autonomous functionality
Attitude Control	Spin-stabilized (1 Hz), Torquer coils
Attitude Determination	Sun Sensor, Magnetometer
Navigation	GPS (< 1 μs, < 10 m rms)
Mass	< 1.08 kg (with contingency)
Required Load Power	< 0.82 W average (with contingency)
Battery Capability	9.61 W-hr total
EOL Generated Power	2.40 W average
Comm Link Rate	S-band: 128 kbits/s down, 128 bits/s up
Onboard Storage	≥ 2 Gbytes (≤ 55 Mbits/day required)
Payload Interface	Integrated with spacecraft





Mission Schedule

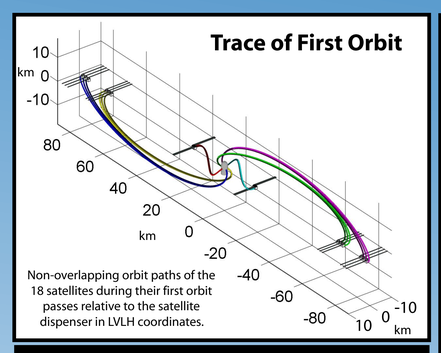
Phases	Start	Finish	Major Milestones	Date
Phase A Study	5/2/08	9/16/08	PDR/CDR	5/14/10
Phase B/C	1/5/09	10/21/10	Confirmation Review	6/14/10
Phase D	5/14/10	7/19/12	MOR	6/15/11
Phase E	7/20/12	1/30/14	PER	8/8/11
Archival/Closeout	1/31/14	2/27/14	PSR	4/5/12
			Launch	7/5/12

Anticipated Launch Vehicle : Pegasus XL with HAPS

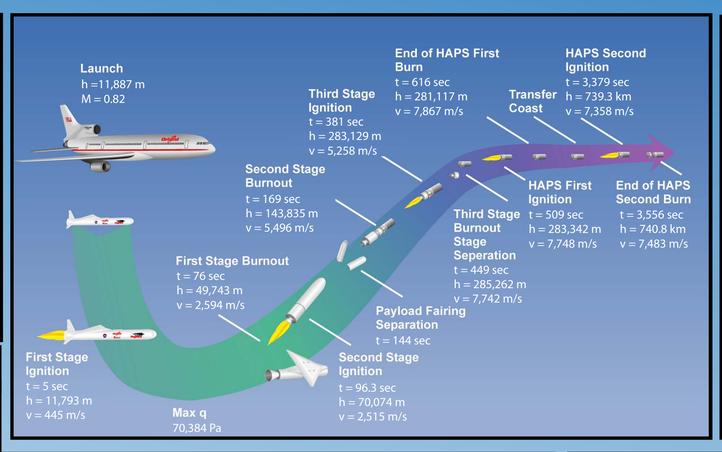
Science Payload

Electric field sensor: Measures *in-situ* DC and AC components
Range ≥ ± 1.5 V/m, Resolution ≤ 60 μV
Two 1-meter booms

HiDEF Launch Profile



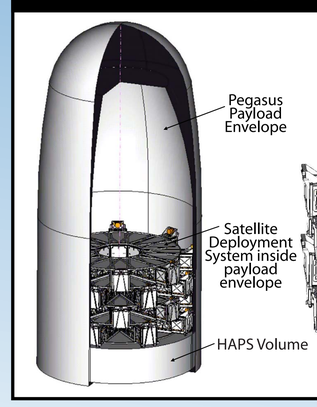
Non-overlapping orbit paths of the 18 satellites during their first orbit passes relative to the satellite dispenser in LVLH coordinates.



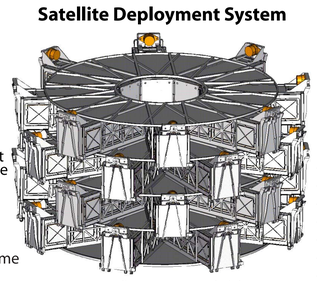
Launch Mass Analysis

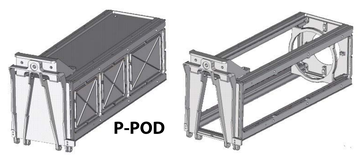
	Unit Mass (kg)	Qty	Contingency	Total (kg)
Deployment				**70.57**
P-PODs	1.17	30	10%	38.61
Structure	20.18	1	20%	24.22
MODAS + Batteries	4.60	1	20%	5.52
Harness	1.85	1	20%	2.22
HAPS				**167.81**
Dry Mass	111.11	1	included	111.11
Propellant	56.70	1	included	56.70
Satellites				**96.75**
Satellites	1.075	90	20%	96.75
TOTAL Pegasus Delivered Mass:				335.13
Pegasus Delivered Mass Capability:				374.75
Pegasus Delivered Mass Margin:				12%
TOTAL HAPS Delivered Mass:				167.32
HAPS Delivered Mass Capability:				200.00
HAPS Delivered Mass Margin:				20%

Satellite Dispenser



Satellite Deployment System





<115 cm diameter, 61.5 cm height

- 4 layers containing up to 8 P-PODs each
- Each P-POD is 45 degrees apart
- Each layer is offset by 22.5 degrees from the next
- Door stoppers will ensure doors do not interfere
- Height kept to a bare minimum to lower CG
- Avionics box location on top plate
- Easy access to rear of P-POD
- P-PODs can be easily removed from the structure

Deployment Parameters for Each Group of 18 Satellites (3 per P-POD Group)

P-POD Group	Deployment Angle*	In-Track Velocity Component	Cross-Track Velocity Component	Differential Precession Rate**
	deg	m/s	m/s	deg/day
1	35	4.1	2.9	-0.69 to -0.72
2	102.5	-1.1	4.9	-0.57 to -0.60
3	170	-4.9	0.9	-0.15 to -0.16
4	215	-4.1	-2.9	+0.15 to +0.16
5	282.5	1.1	-4.9	+0.57 to +0.60
6	350	4.9	-0.9	+0.69 to +0.72

* Measured in the crosstrack direction from the velocity vector
** Rate of precession of orbit relative to HAPS (at time of deployment), the range represents the 515 km to 675 km altitude variation

CLEMSON UNIVERSITY

Space Dynamics LABORATORY
Utah State University Research Foundation

GATS