National Aeronautics and
Space Administration
Goddard Space Flight Center
Greenbelt, MD 20771

February 15, 2007

Reply to Attn of: 410

MEMORANDUM FOR THE RECORD

National Environmental Policy Act (NEPA) Compliance for Time History of Events and Macroscale Interactions During Substorms (THEMIS)

1.0 Introduction

The NEPA of 1969, as amended (42 U.S.C. 4321, *et seq.*), requires Federal agencies to consider the environmental impacts of a project in their decision making process. To comply with NEPA and associated regulations (the Council on Environmental Quality (CEQ) Regulations for Implementing the Procedural Provisions of NEPA [40 CFR Parts 1500-1508] and NASA policy and procedures [14 CFR Part 1216 Subpart 1216.3]), NASA has prepared an Environmental Assessment (EA) for routine payloads launched on Expendable Launch Vehicles (ELVs) from Cape Canaveral Air Force Station (CCAFS) and Vandenberg Air Force Base (VAFB) (Ref: *Final Environmental Assessment for Launch of NASA Routine Payloads on Expendable Launch Vehicles from Cape Canaveral Air Force Station, Florida, and Vandenberg Air Force Base, California*, June 2002). The EA assesses the environmental impacts of missions launched from CCAFS and VAFB with spacecraft that are considered routine payloads.

Spacecraft defined as routine payloads utilize materials, quantities of materials, launch vehicles and operational characteristics that are consistent with normal and routine spacecraft preparation and flight activities at VAFB, CCAFS, and the Kennedy Space Center. The environmental impacts of launching routine payloads from VAFB and CCAFS fall within the range of routine, ongoing and previously documented impacts that have been determined not to be significant. Spacecraft covered by this EA meet specific criteria ensuring that the spacecraft, its operation and decommissioning, do not present any new or substantial environmental or safety concerns.

To determine the applicability of a routine payload classification for a mission launched from VAFB and CCAFS and coverage under the NASA routine payload EA, the mission is evaluated against the criteria defined in the EA using the Routine Payload Checklist (RPC).

2.0 Mission Description

THEMIS is a NASA-funded mission managed by the Explorers Program Office at Goddard Space Flight Center in Greenbelt, Maryland. The Space Science Laboratory at

the University of California at Berkeley is responsible for the project management, science instruments, mission integration, post launch operations and data analysis. Swales Aerospace is responsible for the five Probe busses, as well as the Probe Carrier (PC).

THEMIS is a five-satellite mission with the job of determining the causes of the global reconfigurations of the Earth's magnetosphere that are evidenced in aurora activity, known as the Northern Lights. During the winter months, the satellites (the Probes) will align with the Earth's magnetic tail every four days, allowing the detector instruments to track the aurora disturbances. The satellite data will be combined with observations of the aurora from a network of ground based observatories across Alaska and northern Canada.

The Probes will carry identical suites of electric, magnetic, and particle detectors. The instruments being flown are the: Flux Gate Magnetometers, Electro Static Analyzers, Solid State Telescopes, Search Coil Magnetometers, and Electric Field Instruments. The instruments on the ground consist of the Flux Gate Magnetometers and the All-sky white light imagers.

THEMIS will be launched on a Delta II 7925-10, from CCAFS, with a daily launch window of 20 minutes, into a final orbit of 1.07 x 14.2 Re with an inclination of 13.4 degrees. The five THEMIS Probes will be deployed from the Probe Carrier. The Probes will use on-board hydrazine propulsion to ascend to the ecliptic plane science orbits. The Probe Carrier is a simple mechanical fixture, which stays attached to the launch vehicle third stage in the final transfer orbit.

The duration of the mission is 2 years, which includes sufficient time to capture data from two full magnetic tail seasons. During the mission lifetime, there are two alignment periods each year, which are the crucial observation periods. Beyond the last observation period, the mission would enter extended operations depending on funding and the health of the Probes. The hardware must meet a two-year life requirement.

In accordance with NASA Policy for Limiting Orbital Debris Generation (NPD 8710.3) and NASA Safety Standard, Guidelines and Assessment Procedures for Limiting Orbital Debris (NSS 1740.14), an Orbital Debris Analysis (ODA) has been generated for the mission. Each Probe is required to provide enough fuel to meet the 2-year mission objectives, plus sufficient reserve fuel for an end of mission depletion burn, which will result in a passive re-entry within 25 years. The ODA analyses for the Probes show a debris casualty area of 2.2650 m^2, which meets the guideline of less than 8 m^2. For the third stage and Probe Carrier, the only pieces of equipment to survive re-entry are the Star-48 rocket motor case assembly, the rocket nozzle, and the Probe Carrier main deck. From an analysis for the Delta II third stage, it was determined that the resulting casualty area will be 7.7381 m^2. The Delta II second stage slightly exceeds the casualty risk guideline.

The components utilized in the THEMIS mission are made of materials normally encountered in the space industry. THEMIS will not use any lasers or radioactive

materials and will not carry any pathogenic organisms. The THEMIS mission will not pose any substantial hazards or environmental concerns.

3.0 NASA Routine Payload Determination

The THEMIS mission has been evaluated against the NASA routine payload EA for launches from CCAFS and VAFB, using the RPC (see enclosed Evaluation Recommendation Package). The evaluation indicates that the mission meets the criteria for a routine payload. The mission does not present any unique or unusual circumstances that could result in new or substantial environmental impacts. Based on this review, it is determined that the THEMIS mission qualifies as a routine payload and falls within the scope of the reference routine payload EA. No additional NEPA action or documentation is required.

for Edward J. Weiler
Director

Enclosure

EVALUATION RECOMMENDATION PACKAGE

Record of Environmental Consideration
Routine Payload Checklist
NEPA Environmental Checklist

Enclosure

RECORD OF ENVIRONMENTAL CONSIDERATION

1. Project Name: Time History of Events and Macroscale Interactions during Substorms (**THEMIS**)

2. Description/location of proposed action: Mission to study the time history of auroral breakup and magnetospheric current disruption.

   Date and/or Duration of project: Launch 2/2007

3. It has been determined that the above action:

__X__ a. Is adequately covered in an existing EA or EIS.
   Title: *Final Environmental Assessment for Launch of NASA Routine Payloads on ELVs from CCAFS, Florida and VAFB, California*
   Date: June 2002

___ b. Qualifies for Categorical Exclusion and has no special circumstances which would suggest a need for and Environmental Assessment.
   Categorical Exclusion:

___ c. Is exempt from NEPA requirements under the provisions of:

___ d. Is covered under EO 12114, not NEPA.

___ e. Has no significant environmental impacts as indicated by the results of an environmental checklist and/or detailed environmental analysis.
   (Attach checklist or analysis as applicable)

___ f. Will require the preparation of an Environmental Assessment.

___ g. Will require the preparation of an Environmental Impact Statement.

___ h. Is not federalized sufficiently to qualify as a major federal action.

Beth Montgomery — NEPA Program Manager, Code 250 — 1/25/07
Beth Montgomery — Date

Frank Snow — Project Manager, Code 410 — 1/25/07
Frank Snow — Date

NASA Routine Payload Checklist (1 of 2)

PROJECT NAME: **THEMIS** DATE OF LAUNCH: October 19, 2006

PROJECT CONTACT: Frank Snow PHONE NUMBER: 301-286-7494 MAILSTOP: 410

PROJECT START DATE: 5/7/03 (start Phase B) PROJECT LOCATION: University of California, Berkeley

PROJECT DESCRIPTION: Study the time history of auroral breakup and magnetospheric current disruption

A. SAMPLE RETURN:	YES	NO
1. Would the candidate mission return a sample from an extraterrestrial body?		X
B. RADIOACTIVE SOURCES:	YES	NO
1. Would the candidate spacecraft carry radioactive materials?		X
2. If Yes, would the amount of radioactive sources require launch approval at the NASA Associate Administrator level or higher according to NPG 8715.3 (NASA Safety Manual)?		
Provide a copy of the Radioactive Materials Report as per NPG 8715.3 Section 5.5.2.		
C. LAUNCH AND LAUNCH VEHICLES:	YES	NO
1. Would the candidate spacecraft be launched using a launch vehicle/launch complex combination other than those indicated in Table 1 below?		X
2. Would the proposed mission cause the annual launch rate for a particular launch vehicle to exceed the launch rate approved or permitted for the affected launch site?		X
Comments:		
D. FACILITIES:	YES	NO
1. Would the candidate mission require the construction of any new facilities or substantial modification of existing facilities?		X
2. If Yes, has the facility to be modified been listed as eligible or listed as historically significant?		
Provide a brief description of the construction or modification required:		
E. HEALTH AND SAFETY:	YES	NO
1. Would the candidate spacecraft utilize any hazardous propellants, batteries, ordnance, radio frequency transmitter power, or other subsystem components in quantities or levels exceeding the Envelope Payload characteristics (EPCs) in Table 2 below?		X
2. Would the candidate spacecraft utilize any potentially hazardous material as part of a flight system whose type or amount precludes acquisition of the necessary permits prior to its use or is not included within the definition of the Envelope Payload (EP)?		X
3. Would the candidate mission release material other than propulsion system exhaust or inert gases into the Earth's atmosphere or space?		X
4. Would launch of the candidate spacecraft suggest the potential for any substantial impact on public health and safety?		X
5. Would the candidate spacecraft utilize a laser system that does not meet the requirements for safe operation (ANSI Z136.1-2000 and ANSI Z136.6-2000)? For Class III-B and IV laser operations, provide a copy of the hazard evaluation and written safety precautions (NPG 8715.3).		X
6. Would the candidate spacecraft contain pathogenic microorganisms (including bacteria, protozoa, and viruses) which can produce disease or toxins hazardous to human health?		X
Comments: The THEMIS mission Orbital Debris Assessment (ODA) is complete and reviewed by KSC and GSFC, Code Q approval is pending.		

continued on next page

NASA Routine Payload Checklist (2 of 2)

PROJECT NAME: **THEMIS** DATE OF LAUNCH: October 19, 2006

PROJECT CONTACT: Frank Snow PHONE NUMBER: 301-286-7494 MAILSTOP: 410

PROJECT START DATE: 5/7/03 (start Phase B) PROJECT LOCATION: University of California, Berkeley

PROJECT DESCRIPTION: Study the time history of auroral breakup and magnetospheric current disruption

F. OTHER ENVIRONMENTAL ISSUES:	YES	NO
1. Would the candidate spacecraft have the potential for substantial effects on the environment outside the United States?		X
2. Would launch and operation of the candidate spacecraft have the potential to create substantial public controversy related to environmental issues?		X
Comments:		

Table 1: Launch Vehicles and Launch Pads

Launch Vehicle	Eastern Range (CCAFS Launch Complexes)	Western Range (VAFB Space Launch Complexes)
Atlas IIA & AS	LC-36	SLC-3
Atlas IIIA & B	LC-36	SLC-3
Atlas V Family	LC-41	SLC-3
Delta II Family	LC-17	SLC-2
Delta III	LC-17	N/A
Delta IV Family	LC-37	SLC-6
Athena I & II	LC-46 or -20	California Spaceport
Taurus	LC-46 0r -20	SLC-576E
Titan II	N/A	SLC-4W
Pegasus XL	CCAFS skidstrip KSC SLF	VAFB airfield

Table 2: Summary of Envelope Spacecraft Subsystems and Envelope Payload Characteristics (EPC)

Structure	**Unlimited:** aluminum, magnesium, carbon resin composites, and titanium **Limited:** beryllium [50 kg (110 lb)]
Propulsion	Mono- and bipropellant fuel; 1000 kg (2200 lb) (hydrazine); 1000 kg (2200 lb) (monomethyhydrazine) Bipropellant oxidizer; 1200 kg (2640 lb) (nitrogen tetroxide) Ion-electric fuel; 500 kg (1100 lb) (Xenon) SRM; 600 kg (1320 lb) (AP)-based solid propellant
Communications	Various 10-100 W (RF) transmitters
Power	Solar cells; 150 A-Hr (Ni-H_2) battery; 300 A-Hr (LiSOC) battery; 150 A-Hr (NiCd) battery
Science instruments	10 kW radar ANSI safe lasers (Section 4.1.2.1.3)
Other	Class C EEDs for mechanical systems deployment Radioisotopes limited to quantities that are approved for launch by NASA Nuclear Flight Safety Assurance Manager Propulsion system exhaust and inert gas venting

NEPA Environmental Checklist

1. Project/Program

THEMIS – Time History of Events and Macroscale Interactions during Substorms

2. Points of Contact

Mission Manager: Frank Snow	Code: 410	301-286-7494
Observatory Manager: John Thurber	Code: 410	301-286-8360
PI: Vassilis Angelopoulos	Code: UCB	510-643-1871
Project Manager: Peter Harvey	Code: UCB	510-642-0643

3. Schedule

Formulation Process (Phase A/B): Start ΦA, 6/15/02; Start ΦB, 5/7/03
Implementation Process (Phase C/D): Start ΦC, 11/14/03; Start ΦD, 06/18/04
Launch Date: October 19, 2006

4. Current status

Project is preparing for the Confirmation Readiness Review with GSFC PMC and Code S Confirmation Review at NASA/HQ on February 4, 2004 and March 2004, respectively.

5. Project Description

a. Purpose/Need: Study the time history of auroral breakup and magnetospheric current disruption

b. Spacecraft/Instruments: 5 spin-stabilized micro-probes with the following instruments: EFI (Electric Field Instrument), ESA (Electro Static Analyzer), FGM (Flux Gate Magnetometer), SCM (Search Coil Magnetometer), and SST (Solid State Telescope)

c. Launch Vehicle: Delta 7925-10C

d. Launch Site: Kennedy Space Center, Florida

e. Alternatives (to or for the mission): There are no alternatives for this MIDEX mission.

f. NASA's Involvement/Responsibility: NASA provides programmatic support to the UCB Project office to ensure mission success.

g. Participants/Locations: University of California, Berkeley, Space Sciences Laboratory, (ESA, EFI, SST, Magnetometer Booms, Data Processing Unit); Swales Aerospace, Beltsville, Maryland (Probe Bus and Carrier); Technical University of Braunschweig, Germany and Institt fur Weltraumforschung, Austria (FGM); Centre

d'étude des Environnements Terrestre et Planetaires, France (SCM); Universities of Calgary and Alberta, Canada (Ground Based Observatory, GBO)

h. Mission Life: 2 years

i. End of mission, Re-entry: Probes are designed to perform re-entry burns at the end of mission. Launch vehicle upper stages will meet the 25 year re-entry requirement

6. Is there anything controversial about the mission?

No

7. Is there anything unique, unusual, exotic about the mission, spacecraft, and instruments?

No

8. Is there any environmental documentation for spacecraft, launch vehicle (NEPA or EO12114)?

No additional NEPA documentation for the spacecraft.

9. Is the mission compliant with NASA policy and guidelines for Orbital Debris? (NPD 8710.3 and NSS 1740.14)

The Project has generated an Orbital Debris Analysis (ODA), which is compliant to NSS 1740.14. THEMIS mission ODA is available upon request.

10. Has an Air Force Form 813 been completed? (Please attach copy)

N/A

11. Does the mission include or involve:

Check all that apply. If uncertain indicate with a "?"
For all that apply provide an explanation. Use the additional space below if needed.

X a. Fuels: Monopropellant Hydrazine fuel
____ b. Radioactive Material_____
X c. Explosives: NASA Standard Initiator (NSI) is a Class C EED
____ d. Chemicals_____
____ e. Hazardous Materials/Substances_____
____ f. Lasers (Class, Earth Pointing)_____
____ g. Disease Producing Pathogenic Microorganisms_____
____ h. Construction/Modification of a Facility_____
____ i. Discharges of any substances into air, water, or soil_____
____ j. Generation/Use/Storage/Disposal of Toxic or Hazardous Substances____
____ k. Generation of Hazardous Wastes_____

_____l. Generation of High Noise Levels_____
_____m. Sample Return to Earth_____
_____n. Generation of Ionizing or Nonionizing Radiation_____
_____o. Impact on Local Social or Economic Conditions_____
_____p. Removal of Vegetation or Destruction of Habitat_____
_____q. Impact/Affect on Minority or Low Income Populations_____
_____r. Affect Any Threatened or Endangered Species_____
_____s. Affect Areas of Historical or Cultural Significance_____
_____t. New or Foreign Launch Vehicle_____
_____u. Other Issues of Potential Environmental Impact_____

12. What hazards are associated with the mission?

Hazards include electrical, hazardous materials, equipment handling, and general industrial hazards. THEMIS mission MSPSP identifies all launch vehicle integration hazards. Currently, the THEMIS MSPSP is in final review with GSFC Safety, and a copy is available upon request.

Frank Snare
Mission Manager, Code

June 2, 2006
Date

Explanations

Summary of THEMIS Subsystems

Structural Materials	Aluminum (6061-T651, 7075-T7351 plate and 5056 honeycomb); graphite composite (M55/RS-3)
Propulsion	Monopropellant hydrazine 193.5 kg. (425.7 lb)
Communications	5 W, S-band transmitter
Power	GaAs solar cells (body mounted), 10.5 A-Hr Lithium-Ion battery
Science instruments	EFI – Electric Field Instrument ESA – Electro Static Analyzer FGM – Flux Gate Magnetometer SCM – Search Coil Magnetometer SST – Solid State Telescope
Other (include dimensions and weight of s/c)	Class C [DOT class 1.4S] EEDs, (10 total) used for the probe separation system

National Aeronautics and
Space Administration
Headquarters
Washington, DC 20546-0001

January 18, 2007

Reply to Attn of: Science Mission Directorate

TO: Chief Safety and Mission Assurance Officer

FROM: Associate Administrator for Science Mission Directorate

SUBJECT: Acceptance of Time History of Events and Macro Scale Interactions during Substorms (THEMIS) Orbital Debris Assessment

SMD has received the Orbital Debris Assessment (ODA) from the THEMIS project and the evaluation of the ODA by the Safety and Mission Assurance (S&MA) Office. The S&MA assessment found that THEMIS was noncompliant in two areas associated with the Boeing Delta II 7925-10 launch vehicle and one area associated with the spacecraft.

The launch vehicle non-compliances are characteristic of the Delta II fleet and are customarily waived. The THEMIS launch vehicle does not meet guidelines 4-1 and 7-1 of the NASA Safety Standard 1740.14. Guideline 4-1 states that probability of accidental explosion should be less than $1e^{-4}$; the analyzed value for the THEMIS launch vehicle second stage is $3.5460e^{-4}$. Guideline 7-1 states that probability of casualty on re-entry should not exceed $1e^{-4}$; current analyzed value is $1.2121e^{-4}$ for the THEMIS launch vehicle.

The spacecraft non-compliance, which applies to all five THEMIS spacecrafts, is related to elimination of stored energy sources. Guideline 4.2 in NASA Safety Standard 1740.14 states that all on-board sources of stored energy are to be depleted at the end of mission in order to limit the risk to other space systems from accidental explosions after completion of mission operations. The THEMIS battery charging circuit can not be disabled, thus the spacecraft batteries can not be left in a permanently discharged state. SMD has considered the cost and risk of making changes to this established spacecraft bus and accepts the current design. It should be noted that this risk is somewhat mitigated by the ability of each spacecraft to perform a depletion burn for subsequent passive re-entry within five years following end of mission (guideline is 25 years for re-entry).

In accordance with NASA Policy Directive 8710.3B, SMD accepts these non-conformances to NASA guidelines on limiting debris and accepts the associated risks.

Mary L. Cleave

cc:
Science Mission Director/Dr. Hartman
- Mr. Luther
- Mr. Komar
- Mr. Ledbetter
- Dr. Fisher
- Mr. Gay
- Dr. C. Pollock
- Mr. Jenkins

Safety and Mission Assurance Office
- Mr. J. Lyver

THEMIS ORBITAL DEBRIS ASSESSMENT COMPLIANCE MATRCIES

The THEMIS Orbital Debris Assessment (ODA) was submitted to NASA/HQ in February 2006. The project's ODA is based on detailed document entitled "THEMIS Orbital Debris Final Assessment", SAI-RPT-0579 (Rev. C), dated January 26, 2006. A summary of the current Probe compliance status is provided in Table ES-1, and LV compliance is provided in Table ES-2.

Each Probe is required to provide enough fuel to meet the two-year mission objectives, plus sufficient reserve fuel for an end of mission depletion burn, which will result in a passive re-entry within 25 years. The ODA analyses for the Probes show a debris casualty area of 2.2650 m^2, which meets the guideline of less than 8 m^2. For the third stage and Probe Carrier, the only pieces of equipment to survive reentry are the Star-48 rocket motor case assembly, the rocket nozzle, and the Probe Carrier main deck. From a KSC (DAS 1.5.3) analysis for the Delta II third stage, it was determined the resulting casualty area will be 7.7381 m^2.

Table ES-1 Probe Orbital Debris Guideline Compliance Status

GUIDELINE	DESCRIPTION	MET	NOT MET	N/A	IMPACT/ISSUE
3-1	Operational Debris - LEO	X			
3-2	Operational Debris - GEO	X			
4-1	Accidental Explosion During Mission	X			
4-2	Accidental Explosion After Mission	X			
4-3	Intentional Breakup- Long-term Risk			X	
4-4	Intentional Breakup- Short-term Risk			X	
4-5	Intentional Breakup- During Reentry			X	
5-1	Collision with Large Objects	X			
5-2	Collision with Small Objects	X			
6-1	Disposal – LEO	X			
6-2	Disposal – Above LEO			X	
6-3	Disposal – 12 Hour Orbits			X	
6-4	Disposal Reliability	X			
7-1	Reentry Survivability	X			

Table ES-2 Launch Vehicle (LV) Orbital Debris Guideline Compliance Matrix

GUIDELINE	DESCRIPTION	MET	NOT MET	N/A	IMPACT/ISSUE
3-1	Operational Debris - LEO	X			
3-2	Operational Debris - GEO	X			
4-1	Accidental Explosion During Mission		X		2nd and 3rd Stage probability of explosion both exceed 0.0001
4-2	Accidental Explosion After Mission	X			
4-3	Intentional Breakup- Long-term Risk			X	
4-4	Intentional Breakup- Short-term Risk			X	
4-5	Intentional Breakup- During Reentry			X	
5-1	Collision with Large Objects	X			
5-2	Collision with Small Objects			X	
6-1	Disposal – LEO	X			
6-2	Disposal – Above LEO			X	
6-3	Disposal – 12 Hour Orbits			X	
6-4	Disposal Reliability			X	
7-1	Reentry Survivability		X		2nd stage slightly exceeds casualty risk guideline

Launch Vehicle Non-Compliance

Guideline 4-1. The probability of explosion of the 2nd and 3rd stages in Earth orbit exceed Guideline 4-1 threshold value of .0001. To bring this parameter into compliance with the NSS 1740.14 guideline, redesign of the 2nd stage, 3rd stage and related hardware would be required. A standard waiver maybe needed, if required.

Guideline 7-1. According to the KSC analysis, the total Delta II, 2nd stage, reentry risk is 1.2121e-4, which violates NSS 1740.14 Guideline 7-1. Compliance with the 0.0001 guideline would require redesign of the 2nd stage. Therefore, a standard waiver maybe needed for the launch vehicle 2nd stage non-compliance on Guideline 7.1.