National Aeronautics and Space Administration

Goddard Space Flight Center
Greenbelt, MD 20771

August 25, 2010

Reply to Attn of: 430

MEMORANDUM FOR THE RECORD

The National Environmental Policy Act (NEPA) Compliance for Mars Atmosphere and Volatile Evolution Mission (MAVEN)

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 spacecraft launched from VAFB and CCAFS, the mission is evaluated against the criteria defined in the EA using the Routine Payload Checklist (RPC).

Mission Description

The driving theme of the Mars Exploration Program is to understand the role of water on Mars and its implications for possible past or current biological activity. The Mars Atmosphere and Volatile Evolution (MAVEN) mission will determine the role that the loss of volatiles to space has played through time, allowing us to understand the histories of the atmosphere and climate, liquid water, and habitability on the Red Planet. MAVEN will do this by providing a comprehensive picture of the present state of the upper atmosphere and ionosphere of Mars and the processes controlling these regions. This will enable scientists to project processes backward in time to better understand atmospheric and volatile evolution. MAVEN will provide definitive answers to high-priority science questions concerning atmospheric loss to space, and will greatly enhance our understanding of the climate history of Mars.

Tantalizing hints about some of the possible atmospheric loss processes have been provided by previous spacecraft measurements. While these measurements tell us that escape is taking place, no measurements exist that tell us how the processes operate quantitatively, what the total escape rate is today, or how we can extrapolate to other epochs. Determining the impact on climate of loss to space requires the comprehensive and quantitative measurements that MAVEN will make. These measurements will address all regions of the upper atmosphere and of near-Mars space from which escape occurs and that control the escape rates and composition.

MAVEN will accomplish its science mission goals using a suite of high-heritage scientific instruments. MAVEN instruments are grouped into three packages:

Particles and Fields Package:
Supra-Thermal and Thermal Ion Composition (STATIC) instrument
Solar Wind Electron Analyzer (SWEA)
Solar Wind Ion Analyzer (SWIA)
Dual Vector Fluxgate Magnetometer (MAG)
Solar Energetic Particle instrument (SEP)
Langmuir Probe and Waves (LPW) instrument

Remote Sensing Package:
Imaging UltraViolet Spectrograph (IUVS)

Mass Spectroscopy Instrument:
Neutral Gas and Ion Mass Spectrometer (NGIMS)

In addition to the science payload, MAVEN will carry an engineering package consisting of the Electra Ultra High Frequency (UHF) communications system that will provide data relay support services to current and/or future Mars missions.

The baseline launch vehicle for the MAVEN mission will be an Evolved Expendable Launch Vehicle (EELV) class Delta IV or Atlas V. The EELV with MAVEN aboard will launch from Cape Canaveral Air Force Station (CCAS) in late fall of 2013. The launch vehicle will deliver the MAVEN spacecraft into a targeted parking orbit. After a coast period, MAVEN will be injected onto its interplanetary transfer trajectory. Orbiter separation occurs after the end of the second burn. The launch ascent profile and launch trajectory sequence of events includes boost, parking orbit, and injection.

NASA Routine Payload Determination

The MAVEN mission has been evaluated against the criteria established in the 2002 NASA Routine Payload (NRP) EA for launches from CCAFS and VAFB, using the Routine Payload Checklist and the Envelope Payload Characteristics (EPC) (see enclosed Evaluation Recommendation Package).

The MAVEN spacecraft will utilize 1,639 kg (3,282 lbs) of hydrazine. This amount of hydrazine is greater than the threshold listed in the EPC of the current NRP EA. The threshold limit of hydrazine for a payload is 1,000 kg (2,200 lbs). Propellant loads for certain NRP EA approved launch vehicles, such as the Delta II which carries 2,064 kg (4,550 lb) of Aerozine-50 hydrazine, exceed the 1,639 kg propellant load planned for MAVEN. To evaluate impacts in the NRP EA, the Delta II was used as the bounding case for the largest hypergolic load from CCAFS. The NRP EA and other NEPA documentation concluded that these quantities of hydrazine do not create a substantial impact. The launch vehicle for the MAVEN mission will not use hydrazine as a fuel. The amount of hydrazine utilized for the MAVEN mission (launch vehicle/spacecraft combination) is less than the amount of hydrazine on the Delta II and is within the bounds that were considered for assessing the environmental impacts in the NRP EA. In addition, an assessment of the survivability of the MAVEN hydrazine tank and its contents during various launch malfunction scenarios was done to evaluate the potential for a ground release of hydrazine. The results of the assessment indicate that an unplanned reentry would not result in a ground level release of hydrazine. Thus, the hydrazine propellant aboard the MAVEN spacecraft is not expected create a substantial environmental impact and no new or additional impacts are anticipated beyond what was considered in the NRP EA.

The proposed MAVEN mission has been reviewed in accordance with the Routine Payload criteria established in the "*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*," dated June 2002 and the Finding of No Significant Impact (FONSI), dated June 18, 2002. Based on this review, it is determined that the MAVEN mission falls within the scope of the reference EA and the mission is hereby designated as a NASA Routine Payload. The MAVEN mission will have no significant impact, individually or cumulatively, on the quality of the human environment.

At this point no additional NEPA action or documentation is required. However, NASA is in the process of updating the NASA Routine Payload EA. Once the Agency issues the final updated EA, NASA will review the potential environmental impacts of the proposed MAVEN mission in the context of the new analysis and information contained in the updated EA. If NASA determines that there are substantial new circumstances or information relevant to environmental concerns and bearing on the proposed action or its impacts, NASA will formally reopen the NEPA process for this mission.

8/10/10

George W. Morrow — Date
Director of Flight Projects

8/24/10

Robert Strain — Date
Director

Enclosure

EVALUATION RECOMMENDATION PACKAGE

Record of Environmental Consideration
Routine Payload Checklist
NEPA Environmental Checklist
MAVEN Fuel Tank Reentry Survivability Study

Enclosure

RECORD OF ENVIRONMENTAL CONSIDERATION

1. Project Name: Mars Atmosphere and Volatile Evolution Mission (MAVEN)

2. Description/location of proposed action: Mission to determine the role that loss of volatiles from the Mars atmosphere to space has played through time, allowing us to understand the histories of Mars' atmosphere and climate, liquid water and planetary habitability.

   Date and/or Duration of project: November 2013

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 (signature) — 8/5/2010
Beth Montgomery NEPA Program Manager, Code 250 — Date

David F. Mitchell (signature) — 8/5/10
David Mitchell Project Manager, Code 430 — Date

NASA Routine Payload Checklist

PROJECT NAME: **Mars Atmosphere and Volatile Evolution Mission (MAVEN)**		DATE OF LAUNCH:	November 18, 2013
PROJECT CONTACT: David F. Mitchell		PHONE NUMBER: 301-286-0415	MAILSTOP: 430
PROJECT START DATE: January 8, 2007		PROJECT LOCATION:	Goddard Space Flight Center
PROJECT DESCRIPTION: Mars Upper Atmospheric Mission			

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 (EPC's) 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: Propulsion system currently requires 1639 kg of hydrazine. This amount could change as the system design matures.		

NASA Routine Payload Checklist (continued)

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PROJECT DESCRIPTION:	Mars Upper Atmospheric Mission		

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 Or -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

Environmental Checklist for Flight Projects

1. Project/Program

Mars Atmosphere and Volatile Evolution Mission (MAVEN)

2. Points of Contact

Project Manager: David F. Mitchell Code:430 Telephone:301-286-0415

3. Schedule

Formulation Process (Phase A/B): Jan. 8, 2007 – October 2010

Implementation Process (Phase C/D): November 2010 – December 2013

Launch Date: November 18, 2013- December 7, 2013

PDR/CDR: July 2010/July 2011

4. Current status

In Phase B

5. Project Description

a. Purpose: Determine the role that loss of volatiles from the Mars atmosphere to space has played through time, allowing us to understand the histories of Mars' atmosphere and climate, liquid water and planetary habitability.

b. Spacecraft: Sun-pointing, three-axis-stabilized spacecraft with a fixed high-gain antenna, two fixed solar arrays, and one two-axis gimbal to articulate planet-pointing instruments.

c. Instruments: Neutral Gas and Ion Mass Spectrometer (NGIMS), Magnetometer (Mag), Langmuir Probe and Waves (LPW), Solar Wind Ion Analyzer (SWIA), Solar Wind Electron Analyzer (SWEA), Solar Energetic Particle (SEP) detector, Supra-Thermal and Thermal Ion Composition (STATIC), Imaging Ultraviolet Spectrometer (IUVS), Extreme Ultraviolet Monitor (EUVM)

d. Launch Vehicle: EELV

e. Launch Site: Kennedy Space Center

f. NASA's Involvement/Responsibility: NASA/GSFC is managing the mission for the PI and providing two instruments.

g. Participants/Locations: U of Colorado-Boulder; U of Cal, Berkeley; Lockheed Martin – Denver; NASA/GSFC, Greenbelt MD; NASA/JPL Pasadena CA

h. End of Mission, Re-entry: Mars mission, no re-entry planned at end of mission.

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)?

Routine Payload EA.

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

Yes.

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

No

11. During any phase does the mission/project 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 1639 kg of hydrazine
_____ b. Radioactive Materials
_____ c. Explosives
_____ d. Chemicals/Hazardous Materials/Substances
_____ e. Lasers (Class, Earth Pointing)
_____ f. Disease Producing Pathogenic Microorganisms
X g. Discharges of any substances into air, water, or soil Inert Gas release
_____ h. Generation of Hazardous Wastes
_____ i. Generation of High Noise Levels
_____ j. Sample Return to Earth
_____ k. Generation of Ionizing or Non-ionizing Radiation
_____ l. Construction/Modification of a Facility
_____ m. Land Disturbance, Tree Clearing, Removal of Vegetation

______n. Impact on Threatened or Endangered Species______________________________
______o. Impact/Destruction of Sensitive Wildlife Habitat__________________________
______p. Impact on/near Areas of Historical or Cultural Significance________________
______q. Impact on Local Social or Economic Conditions___________________________
______r. Impact on Minority or Low Income Populations___________________________
______s. New or Foreign Launch Vehicle____
______t. Other Issues of Potential Environmental Impact___________________________
______u. Require any Environmental Permit______________________________________

12. What hazards are associated with the mission?

Normal hazards associated with instrument and spacecraft development and operations: pressurized systems, propulsion systems, ground handling/lifting, instrument high voltages,

13. Summary of Subsystems/Components

Structural Materials	Composite Construction, Stiff panel/clip design
Propulsion	Monopropellant design, 1639 kg of hydrazine Propellant Tank: Shell is all Titanium 6AL-4V Minimum wall thickness is 0.031"
Communications	Redundant X-band system
Power	12 m^2 UTJ Solar cell area – 3700 watts (BOL) Dual 55 Ah Li Ion batteries
Science Instruments	Neutral Gas and Ion Mass Spec. (NGIMS), Magnetometer (MAG), Langmuir Probe and Waves (LPW), Solar Wind Electron Analyzer (SWEA), Solar Wind Ion Analyzer (SWIA), Pickup Ion Composition Spectrometer (PICS), Solar Energetic Particle Detector (SEP), Supra-Thermal and Thermal Ion Composition (STATIC), Imaging Ultraviolet Spectrometer (IUVS), Extreme Ultraviolet Solar Monitor (EUVM)
Hazardous Components (radioactive materials, lasers, chemicals, etc.)	None
Other (include dimensions and weight of s/c)	Approx: W, 2.1 m; L, 2.1 m; H 3.2 m (Solar Array folded) W, 2.1 m; L, 8.9 m; H 3.2 m (Solar Array deployed) Dry mass: 903 kg Wet mass: 2550 kg

David F. Mitchell, Code 430

Project Manager, Code

8/5/10

Date

Explanations

MAVEN Fuel Tank Reentry Survivability Study

Orbital Debris Program Office, JSC
2 August 2010

An ORSAT analysis was performed for the MAVEN fuel tank to evaluate its survivability under a variety of launch malfunction scenarios. Material and dimensional specifications were acquired from the "Technical Specification for MAVEN Propellant Tank" (Document Number MAV-RQ-09-0055, Revision 15, October 2009), the presentation "Propulsion Subsystem PDR", and from e-mail correspondence with members of the MAVEN Project team from GSFC. Presented below are a description of the tank, the assumptions made to model the tank's reentry, and the results of the analysis.

Fuel Tank Description

The MAVEN fuel tank is manufactured from Titanium 6 Al-4Vand has an empty mass of 83.10 kg (including the PMD). The tank is a 1.245-m diameter cylindrical tank with hemispherical end caps design to hold 1640 kg of N2H4 fuel pressurized to a maximum expected operating pressure (MEOP) of 1.72 E+6 Pascal using He gas. The stated burst pressure for the MAVEN tank is at least 1.5 MEOP, or 2.58 E+6 Pascal. For this analysis burst pressures of 2.0 MEOP and 3.0 MEOP were considered.

The propellant management device (PMD) selected for the fuel tank negates the need for a bladder to separate the fuel from the pressurant, resulting in only two possible reentry scenarios once the tank breaks free from the parent spacecraft. The first scenario is that both the fill and exit tube for the tank are crimped sufficiently to prevent the escape of the highly pressurized hydrazine. This is an exceptionally improbable event. The second, and more likely scenario, is that one or both of the fill and exit tubes remain open, allowing the fuel to escape.

Launch Malfunction Scenarios

The nominal launch profile includes initial orbital insertion of the launch vehicle upper stage with the payload into a approximately circular orbit with an altitude of 200 km. After a brief coast period, the second stage will reignite to achieve an Earth escape trajectory.

Three basic malfunction scenarios were considered: (1) launch vehicle failure prior to initial orbital insertion, (2) failure of the second stage to reignite, and (3) failure of the second stage shortly after reignition which leaves the spacecraft in an elliptical Earth orbit. In all cases, the upper stage was assumed to release the spacecraft after the malfunction.

In the first two cases, the hydrazine has insufficient time to become frozen and, thus, reenters in a liquid state. In the third case, the orbital lifetime of the spacecraft could be sufficient to allow the hydrazine to freeze. However, in such a case, the offset of the center of mass of the tank should lead to a stable (vice tumbling) orientation upon reentry, which in turn would lead to a burn-through of the tank and the evaporation of the frozen hydrazine.

Therefore, the only case which required further detailed analysis was the unlikely scenario in which the inlet and outlet ports were blocked.

Starting Temperature and Pressure

The parent vehicle was described as rectangular with dimensions 3.0 m x 3.3 m x 2.6 m, with a mass of 2500 kg. The trajectory of this object was modeled from 122 km to the 78 km assumed break-up altitude (where separation of the tank would occur), with an inclination of 28° and an initial relative flight path angle of -0.1°. The trajectory results at 78 km were then used as the initial trajectory for the fuel tank's reentry.

The fuel tank was modeled with varying initial temperatures form 275 K to 315 K. The initial pressure was modeled in two ways: (1) the He pressurant was kept at a constant 1.72 E+6 Pascal and (2) the pressure was allowed to vary with the temperature according to the ideal gas law.

The tanks is predicted to burst for all combinations of initial temperature, initial pressure, and burst pressure. The lowest occurring altitude for this event was 68.3 km, occurring when the initial pressure is a factor of the initial temperature, the temperature is 275 K and the burst pressure is 2.58 E+6 Pascal.

Summary

In the most likely scenarios in which the fuel is released upon initial spacecraft breakup at entry interface, the empty tank survives and impacts the ground with a debris casualty area of 4.46 m^2. This includes the scenario in which the second stage malfunctions prior to orbital insertion but reaches a ballistic apogee of at least 150 km.

In the scenario in which the inlet and outlets are sufficiently blocked to prevent the release of liquid hydrazine, the internal pressure grows and eventually exceeds the design of the tank, resulting in a tank burst and release of the hydrazine.

In the scenario in which the spacecraft is left stranded in a temporary Earth orbit for a length of time in which the hydrazine could freeze, upon reentry the tank will stabilize, leading to a burn-through of the tank and evaporation of the hydrazine.