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National Aeronautics and
Space Administration

Headquarters
Washington, DC 20546-0001

MAY 30 2001

Reply to Attn of: SD

Dr. Michael F. A'Hearn
Department of Astronomy
Computer and Space Science Building
University of Maryland
College Park, MD 20742

Dear Dr. A'Hearn:

As a result of the successful Confirmation Review held May 23, 2001, at NASA Headquarters, I approve the Deep Impact project of the Discovery program to proceed into the Implementation Phase (Phase C/D).

I congratulate the entire Deep Impact Project Team on having risen to the challenge conveyed in my letter to you dated March 30, 2001, by clearly demonstrating the project's readiness to enter implementation. I look forward to seeing the obvious commitment, determination, and energy of your team now focused on the work that lies ahead to implement this exciting mission.

Enclosed you will find the signed Program Level Requirements for the Deep Impact mission, representing Appendix 8 to the Discovery Program Plan.

Sincerely,

Edward J. Weiler

Edward J. Weiler
Associate Administrator
for Space Science

Enclosure

cc:
S/Dr. E. Huckins
  Dr. C. Pilcher
SD/Mr. K. Ledbetter
  Mr. M. Watkins
  Mr. S. Brody
SJ/Dr. R. Parker
  Mr. D. Jarrett
SP/Mr. R. Maizel
  Mr. D. Lee
SR/Dr. J. Bergstralh
  Dr. T. Morgan
PO/Mr. D. Savage
JPL/180-904/Dr. C. Elachi
JPL/264-459/Mr. T. Gavin
JPL/264-472/Mr. C. Jones
JPL/301-350/Mr. B. Muirhead

Appendix 8 to the Discovery Program Plan:
Program Level Requirements for the Deep Impact Discovery Project
May 23, 2001

Appendix 8 to the Discovery Program Plan: Program Level Requirements for the Deep Impact Discovery Project

1. SCOPE

This appendix to the Discovery Program Plan identifies the science, mission, schedule, and cost requirements imposed on the University of Maryland (UMd) and the Jet Propulsion Laboratory (JPL) of the California Institute of Technology (Caltech) for the development and operation of the Deep Impact (DI) Project of the Discovery Program. Requirements begin in Section 4. Sections 1, 2, & 3 are intended to set the context for the requirements that follow.

This document serves as the basis for mission assessments conducted by NASA during the development period and provides the baseline for the determination of the science mission success during the operational phase.

Program authority is delegated from the Associate Administrator for the Office of Space Science (AA/OSS) through the Director of the NASA Management Office (NMO) to the Discovery Program Manager within the NMO. The Principal Investigator (PI) at UMd is responsible for the overall success of the Deep Impact Project and is accountable to the AA/OSS for the scientific success and to the Discovery Program Manager for the programmatic success. The PI will also coordinate the work of the co-investigators and have ultimate responsibility for Deep Impact's outreach efforts.

The JPL Program Management Council (PMC) is the governing PMC for the Deep Impact Project. The JPL Director is responsible for certifying Deep Impact mission readiness to the AA/OSS, through the Discovery Program Office.

The Project Manager (PM), a staff member of the Jet Propulsion Laboratory (JPL), will oversee the technical implementation of the project. The PM is responsible for design, development, test, and mission operations and shall coordinate the work of all Deep Impact partners and contractors.

Changes to information and requirements contained in this document require approval by the Office of Space Science.

2. SCIENCE DEFINITION

2.1. Baseline Science Objectives

2.1.1. Deep Impact Science Objectives

The Deep Impact mission will fly to and impact a short-period comet understood to have a nuclear radius > 2km (large enough so that it will sustain a crater of cometesimal size and ensure reliable targeting). The direct intent of the impact is to excavate a crater of approximately 100 meters in diameter and 25 meters in depth. The overall scientific objectives are to:

1. Dramatically improve the knowledge of key properties of a cometary nucleus and, for the first time, assess directly the interior of a cometary nucleus by means of a massive impactor hitting the surface of the nucleus at high velocity.

2. Determine properties of the surface layers such as density, porosity, strength, and composition from the resultant crater and its formation.

3. Study the relationship between the surface layers of a cometary nucleus and the possibly pristine materials of the interior by comparison of the interior of the crater with the pre-impact surface.

4. Improve our understanding of the evolution of cometary nuclei, particularly their approach to dormancy, from the comparison between interior and surface.

These mission objectives address the area of greatest importance identified by the Committee on Planetary and Lunar Exploration (COMPLEX) in their recommendations on the exploration of primitive bodies – that is the direct exploration of comets by spacecraft, concentrating (in order of priority) on the nucleus, coma, and tail phenomena. Further details are discussed below under the instrument description.

2.1.2. Deep Impact Science Strategy

The Deep Impact mission seeks to achieve the science objectives of Section 2.1.1 by implementing the following science strategy. Because of the very large uncertainty in the cometary environment, the mission is designed for success according to a set of Project Baseline models of the environment, including photometric conditions, dust environment, nuclear shape and topography, and the cratering process. These Project Baseline design models are conservative relative to the best available knowledge but are not an absolute worst case. The mission and instruments are designed to produce results beyond those specified below if a more benign environment than the design models is encountered.

- Obtain visible-wavelength images of the impact site, before impact, with resolution (FWHM = Full-width at Half-maximum of the delivered image) in the range 1 to 10 m to determine the pre-existing topography at the impact site.
- Obtain multi-color, visible-wavelength images sufficient to constrain the size and shape of the nucleus and identify albedo and color heterogeneity on the surface with resolution in the range 50 to 200 m.
- Obtain visible-wavelength images from the flyby spacecraft during the crater-forming event with spatial resolution in the range 50 to 100 m to resolve the growing crater and with sufficient temporal resolution to study the formation process.
- Obtain visible-wavelength images of the ejecta cone with resolution in the range 50 to 200 m to study the formation process of the crater and distinguish various modes of cratering.
- Obtain near-infrared spectra of the ejecta from the crater in order to study the variation in composition with time.
- Obtain visible-wavelength images of the final crater with sufficient spatial resolution to determine the depth and diameter of the crater as a measure of material properties.
- Obtain near-infrared spectra of the final crater and its environs to determine differences between the material in the crater and the exterior material.
- Obtain near-infrared spectra of the coma before impact and after completion of crater formation to assess changes in the outgassing due to the impact.
- Obtain contemporaneous Earth-based (ground and/or Earth-orbit) observations at complementary wavelengths and longer-term Earth-based observations at all wavelengths to evaluate the changes in the behavior of the comet.

2.2. Science Instrument Description

The Deep Impact instrument payload consists of the following:

- High Resolution Imager (HRI)
- Medium Resolution Imager (MRI)
- Impactor Target Sensor (ITS)

The instruments mount separately on the spacecraft and provide data to the spacecraft for storage during the comet encounter.

2.2.1. HRI and MRI

The objectives of the HRI and MRI instruments are:

1. to image parts of the nucleus to reveal details of morphology and processes that will show how comets work;

2. to determine the nuclear size, shape, albedo/color heterogeneity, and activity;

3. to map the composition of nuclear surface and outgassing regions;
4. to assess the level and the composition of the outgassing and how these change due to the impact; and
5. to image the impact ejecta and crater to understand the structure and physical properties of the outer layers of the cometary nucleus.

2.2.2. ITS

The objectives of the ITS instrument are:

1. to image the cometary nucleus for navigation to assure proper targeting;
2. to image part of the surface of the nucleus to determine morphology at the highest resolution; and
3. to image the impact site prior to impact at high enough resolution to determine topographic relief that is a boundary condition for simulating the cratering process.

3. PROJECT DEFINITION

3.1. Project Organization & Management

3.1.1. Organization

The Deep Impact project includes 3 institutional partners with roles specified in Table 1.

Table 1. The Deep Impact Team

Organization/Role	Description & Attributes
University of Maryland	PI, Science and Science Data Center
Jet Propulsion Laboratory	Project management, mission design, autonavigation and fault protection software and mission operations
Ball Aerospace and Technology Corp.	Flyby and Impactor Spacecraft; MRI, HRI, ITS instruments

The organization is shown in Figure 1. The PI is responsible to NASA for all aspects of the mission. JPL provides the overall day-to-day management of the project, BATC provides the spacecraft (including integrated flight software), integration and test, and JPL provides mission operations of the flight system. The payload is to be provided by BATC.

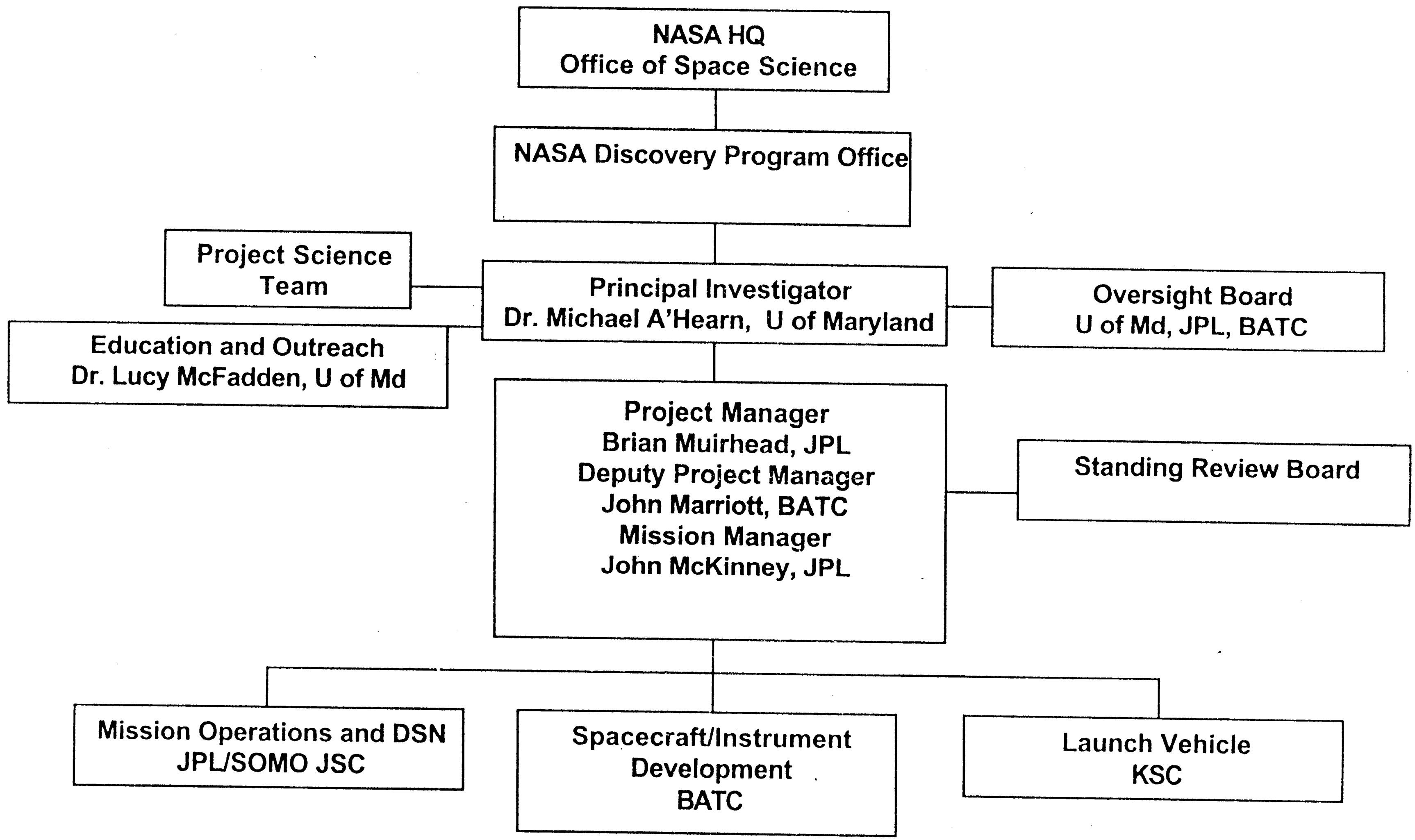

Figure 1. Deep Impact Organization

3.2. Project Acquisition Strategy

UMd provides the PI and the science team for the overall science inputs to the mission design. JPL provides the project management, mission design, systems engineering, and mission operations. Ball Aerospace and Technology Corp. provides the flyby and impactor spacecraft and the HRI, MRI and ITS instruments.

4. PROGRAMMATIC REQUIREMENTS

4.1. Science Requirements

4.1.1. Baseline Science Requirements

The Deep Impact mission will achieve the science objectives of Section 2.1 by meeting the following requirements, which constitute the Baseline Mission Success Criteria. The Deep Impact mission shall:

4.1.1.1. Target a short period comet understood to have a nuclear radius >2 km.

4.1.1.2. Deliver an impactor of mass > 350 kg to an impact on the cometary nucleus at a velocity > 10 km/s. The impact event and crater formation shall be visible from the flyby spacecraft and observable from Earth.

4.1.1.3. Obtain pre-impact visible-wavelength images of the impact site including one with resolution < 3 m and FOV > 50 pixels.

4.1.1.4. Obtain three visible-wavelength images, using at least two different filters, of the entire comet, pre-impact, with resolution < 50 m and average S/N >50 for the illuminated portion of the nucleus.

4.1.1.5. Obtain five visible-wavelength images containing the impact site with resolution < 50 m and showing the crater evolution from within 3 seconds of time of impact until full crater development (assumed to take less than 660 seconds).

4.1.1.6. Obtain five visible-wavelength images of the ejecta cone, showing the ejecta cone evolution at a resolution < 50 m from within 1 second of impact until late in the cone evolution (assumed to take less than 60 seconds).

4.1.1.7. Obtain five near-infrared (1.1 to 4.8 microns), long-slit spectra of the ejecta cone, showing the ejecta cone evolution with spectral resolving power > 200 from within 2 seconds of time of impact until late in the cone evolution (assumed to take less than 60 seconds).

4.1.1.8. Obtain one image of the final crater with a resolution <7 m.

4.1.1.9. Obtain one near-infrared (1.1 to 4.8 microns), long-slit spectrum of the impact region pre-impact and one post impact, both with spectral resolving power >200 and with noise-equivalent-surface-brightness <150 kRayleigh per spectral resolution element at 3.5 microns.

4.1.1.10. Obtain two near-infrared (2.0 to 4.8 microns), long-slit spectra of the coma, one before impact and one after formation of the crater (assumed to take < 660 sec), with spectral resolving power >200 and Noise-equivalent surface brightness <500 kRayleigh per spectral resolution element at 4.7 microns.

4.1.1.11. Obtain at least three Earth-orbital or ground-based datasets of two different types of data complementary to the data from the spacecraft.

4.1.2. Minimum Science Requirements

The following constitute the <u>Minimum Mission Success Criteria.</u> As a minimum, the Deep Impact mission shall:

4.1.2.1. Target a short period comet understood to have a nuclear radius >2 km.

4.1.2.2. Deliver an impactor of >300 kg to an impact on the cometary nucleus at a velocity > 10 km/s.

4.1.2.3. Obtain one visible-wavelength image of the entire comet, pre-impact, with resolution < 100 m and average S/N >50 for the illuminated portion of the nucleus.

4.1.2.4. Obtain two visible-wavelength images with resolution <100 m containing the impact site and showing the crater evolution from within 3 seconds of time of impact until full crater development (assumed to take less than 660 seconds).

4.1.2.5. Obtain two visible-wavelength images of the ejecta cone with resolution < 200 m showing the evolution from within 3 seconds of time of impact until late in the evolution (assumed to take less than 60 seconds).

4.1.2.6. Obtain two near-infrared (1.1 to 4.8 microns), long-slit spectra of the ejecta cone, showing the ejecta cone evolution with spectral resolving power > 200 from within 5 seconds of time of impact until late in the cone evolution (assumed to take less than 60 seconds).

4.1.2.7. Obtain one image of the final crater with resolution <15 m.

4.1.2.8. Obtain at least one Earth-orbital or ground-based dataset of a type complementary to the data from the spacecraft.

4.2. Mission System and Instrument Requirements

4.2.1. Mission Requirements

The Deep Impact baseline mission shall fly to comet Tempel 1. The encounter date shall occur by early July 2005, with the exact date selected to achieve the best possible combination of impactor targeting and comet observability both from the spacecraft and from Earth.

During cruise, the operations team shall perform active testing and calibration to assure the highest level of confidence that the comet encounter will be successful.

During critical spacecraft activities, engineering telemetry for the health and expected performance of the spacecraft shall be provided to ground teams in real time, except in cases where doing so would endanger the health and safety of the spacecraft.

4.2.2. Instrument Requirements

4.2.2.1. All Instrument elements shall survive the launch and mission operations environmental loads.

4.2.2.2. HRI and MRI Instruments

HRI and MRI Instruments shall be designed to obtain visible images of the flyby hemisphere of the comet with an HRI scale of approximately 2 microradians/pixel.

The spectrometer portion of the HRI shall be designed to map the distribution of ices, silicate minerals, and nonvolatile organics at a spatial scale of approximately 10 microradians per pixel and with sensitivity from 1.1 to 4.8 microns to investigate the abundance of volatile species in the outflowing gas.

4.2.2.3. ITS Instrument

The ITS instrument shall be designed to obtain visible images of the comet nucleus as it approaches with a scale of approximately 10 microradians/pixel.

4.2.3. Technology Requirements

A "10/10" technology demonstration experiment, sponsored by the New Millennium Program, is intended to be selected for Deep Impact by the Office of Space Science. Deep Impact shall provide mutually agreed-to accommodations and fly this payload on the mission.

This 10/10 experiment shall, as a minimum, meet the following spacecraft constraints in order to be considered for flight:

- Mass no greater than 10 kg
- Total power needs of no more than 10 w, and only at non-mission critical times
- Meet configuration requirements of Project-provided interface control documents
- Meet Project delivery schedule
- Meet all Project policies with respect to quality and not represent a hazard to meeting the primary mission science objectives.

4.3. Spacecraft

The spacecraft shall provide the required subsystem support in attitude control, propulsion, thermal control, telecommunications, command and data handling, and other systems to satisfy the science, mission, and instrument requirements of sections 4.1 and 4.2.

4.4. Launch Vehicle

The Project shall utilize the Delta 2925 launch vehicle and be ready to launch in the window which opens on January 2, 2004.

4.5. Mission Data

A project data management plan shall be developed to address the total activity associated with the flow of science data, from planning through acquisition, processing, data product generation and validation, to archiving and preservation. Specific requirements to be implemented in the plan are in the following paragraphs.

4.5.1. Downlinked Science Data Requirement

Downlinked science data from the comet encounter shall be collected and distributed to the various instrument specialists for calibration and analysis. Two archival data products shall be created: clean and merged raw science data and calibrated science data. Both products shall be delivered to the Small Bodies Node of the NASA Planetary Data System (PDS) within 6 months of the encounter. All products delivered to the PDS shall be fully compliant with PDS standards.

4.5.2. Early Science Return

Selected images from the comet encounter shall be released in close coordination with NASA immediately after the encounter.

5. NASA MISSION COST REQUIREMENTS

5.1. Cost Cap

The Deep Impact Discovery 8 mission funding is capped at $219.2 million (real year). This includes the design, development, launch, operations, and data analysis for the mission, but excludes the Deep Space Network (DSN) and launch services costs. Including the DSN and launch services costs, the total mission is capped at $279.2 million (real year). Ball Aerospace and Technology Corporation (BATC) is also providing a contribution whose value is $3.7M. The University of Maryland is providing a contribution whose value is >$1M. These BATC and University of Maryland contributions are not included in the cost caps listed in this section.

5.2. Cost Management and Scope Reduction

Provided that Program Level Requirements are preserved, and that due consideration has been given to the use of budgeted contingency and planned schedule contingency, the Deep Impact Project shall pursue scope reduction and risk management as a means to control cost. Section 4.1.2 provides the science floor for the mission; however, reduction in scientific capability shall be implemented only with the concurrence of NASA Headquarters and the Discovery Program Office. Any potential scope reductions affecting these Program Requirements shall be agreed to by the signers of this document (Section 11).

6. MULTI-MISSION NASA FACILITIES

Multi-mission NASA facilities required by the Deep Impact Project shall include launch services facilities and the Deep Space Network (DSN).

7. EXTERNAL AGREEMENTS

There are no other non-NASA organizations (other than Deep Impact team members) that the Deep Impact Project is dependent upon for mission success.

8. PUBLIC OUTREACH AND EDUCATION

The Deep Impact Project shall develop and execute an aggressive public outreach, education, and teaching program consistent with the strategy and approach for education and public outreach defined in the Space Science Enterprise Strategic Plan. The overall outreach effort shall be funded at 1-2% of the development costs.

9. SPECIAL INDEPENDENT EVALUATION

The Deep Impact project is not subject to an Independent Annual Review. The Discovery Program will assess the project's overall mission performance and risk posture using an independent review team. These independent reviews will occur coincident with standard project-level reviews (e.g., Preliminary Design Review, Critical Design Review, etc.), wherever possible, in order to minimize the impact on the Project.

10. TAILORING

No special tailoring for the Deep Impact Project with respect to NPG 7120.5A is necessary beyond that defined as baseline Program-level tailoring for projects of the Discovery Program.

11. APPROVALS

17 May 01

Michael F. A'Hearn Date

Principal Investigator, University of Maryland

5/16/01

Brian K. Muirhead Date

Project Manager, Jet Propulsion Laboratory

5/15/01

Christopher P. Jones Date

Director for Planetary Flight Projects, Jet Propulsion Laboratory

5/16/01

David B. Jarrett Date

Discovery Program Manager, NASA Management Office

5/16/01

Robert A. Parker Date

Director, NASA Management Office

5/17/01

Steven Brody Date

Program Executive, NASA Headquarters

5/22/01

Thomas H. Morgan Date

Program Scientist, NASA Headquarters

5/18/01

Kenneth W. Ledbetter Date

Director, Flight Program Division, NASA Headquarters

5/23/01

Jay T. Bergstralh Date

Science Director for Solar System Exploration (acting), NASA Headquarters

5/23/01

for ~~Edward~~ J. Weiler Date

Associate Administrator for Space Science, NASA Headquarters