REQUEST FOR INFORMATION (RFI)

Concepts for the NASA Gravitational-Wave Mission

General Information

Solicitation Number:	NNH11ZDA019L
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Recovery and Reinvestment Act Action:	No
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Issued by:	Science Mission Directorate

Description

The National Aeronautics and Space Administration (NASA) and its Physics of the Cosmos (PCOS) Program are soliciting information through this Request for Information (RFI) pertaining to potential gravitational-wave science missions. Specifically, NASA is seeking information that can be used to develop concepts that meet some or all of the scientific objectives of the Laser Interferometer Space Antenna (LISA) Mission. Information being sought includes relevant mission concepts, instrument concepts, enabling technologies, or any aspect of flight, ground or launch systems architecture.

In accordance with FAR 15.201(e), the information requested is for planning purposes only and is NOT intended to bind the Government. This RFI is not expected to lead to a future procurement.

Background

The future mission portfolio of NASA's Astrophysics Division is constrained by budgetary resources. The Division is making a concerted effort to control cost growth of future strategic missions through a combination of improved early cost estimation, a more conservative posture of cost reserves, and a reinvigorated technology development program.

Since termination of the NASA/ESA partnership gravitational-wave mission, the Laser Interferometric Space Antenna (LISA), NASA's PCOS Program is developing alternative plans to address high priority scientific objectives described in the 2010 Astrophysics Decadal Survey, "New Worlds, New Horizons" (NWNH) (NRC 2010, http://www.nap.edu/catalog/12951.html).

The PCOS Program Office will work with the science community to develop new gravitational-wave mission concepts satisfying some or all of the scientific objectives listed in Table 1. Such scenarios might include one or more space-based observatories. These scenarios will be presented to the National Research Council's Space Studies Board Committee on Astronomy and

Astrophysics (CAA) for consideration. Recommendations from the CAA will subsequently be used to guide detailed development of scientific, technical, and cost information for future US gravitational-wave missions. Data from these concept studies will also be used to assess future technology needs for the Astrophysics Division. Information from the technology assessment will also be provided to the CAA.

This Request for Information (RFI) is the first step in this process. Through this RFI, NASA is seeking information relevant to gravitational-wave mission concept(s) that will satisfy some or all the scientific objectives listed in Table 1. The RFI also requests standalone instrument concepts as well as relevant key enabling technologies for such missions or instruments. Mission concepts should range in cost from ~ $300M to $2,000M in FY12 dollars.

Science Objectives

Gravitational-wave observations address two of NWNH's top three science objectives: searching for the first stars, galaxies, and black holes; and advancing understanding of the fundamental physics of the universe.

NWNH lists the most important science that LISA could achieve as the following:

- Measurements of black hole mass and spin will be important for understanding the significance of mergers in the building of galaxies;
- Detection of signals from stellar-mass compact stellar remnants as they orbit and fall into massive black holes would provide exquisitely precise tests of Einstein's theory of gravity; and
- Potential for discovery of waves from unanticipated or exotic sources, such as backgrounds produced during the earliest moments of the universe or cusps associated with cosmic strings.

The Panel on Particle Astrophysics and Gravitation, the cognizant implementation panel of the 2010 Astrophysics Decadal Survey, gives a more detailed list of the science from gravitational waves in the form of science questions and the gravitational-wave measurements expected to address those questions, reproduced in Table 1.

<table>
<tr><th colspan="2">Table 1. Science Questions and Gravitational-Wave Measurements</th></tr>
<tr><th>Science Questions</th><th>Measurements Addressing the Questions</th></tr>
<tr><td>How do cosmic structures form and evolve?</td><td>Tracing galaxy-merger events by detecting and recording the gravitational-wave signatures</td></tr>
<tr><td>How do black holes grow, radiate, and influence their surroundings?</td><td>Using gravitational-wave inspiral waveforms to map the gravitational fields of black holes.</td></tr>
<tr><td>What were the first objects to light up the universe, and when did they do it?</td><td>Identifying the first generation of star formation through gravitational waves from core-collapse events.</td></tr>
<tr><td>What are the progenitors of Type Ia supernovae and how do they explode?</td><td rowspan="3">Detecting and recording the gravitational wave signatures of massive-star supernovae, of the spindown of binary systems of compact objects, and of the spins of neutron stars.</td></tr>
<tr><td>How do the lives of massive stars end?</td></tr>
<tr><td>What controls the mass, radius, and spin of compact stellar remnants?</td></tr>
<tr><td>How did the universe begin?</td><td>Detecting and studying very-low-frequency gravitational waves that originated during the inflationary era.</td></tr>
<tr><td>Why is the universe accelerating?</td><td>Testing of general relativity—a deviation from general relativity could masquerade as an apparent acceleration—by studying strong-field gravity using gravitational waves in black hole systems, and by conducting space-based experiments that directly test general relativity</td></tr>
<tr><td colspan="2">Adapted from Panel Reports, New Worlds, New Horizons (NRC 2010, http://www.nap.edu/catalog/12982.html, box 8.2, p. 385)</td></tr>
</table>

A summary of LISA sources, observing performance and associated science can be found in Table 8.1 of the NWNH panel reports (*Panel Reports, New Worlds, New Horizons,* http://www.nap.edu/catalog/12982.html, p. 390). This information is provided in table 2 (below) for reference.

Table 2: Table 8.1 from the Panel report (Panel Reports, New Worlds, New Horizons, http://www.nap.edu/catalog/12982.html, p. 390).

TABLE 8.1 Key Astrophysics Sources for LISA

Source Type and Details	
Massive black hole (MBH) mergers	
Characteristics	Mergers of binaries involving 2 MBHs, with masses in the range of 10^4 to 10^7 $M_{\odot}$, orbital periods of 10^2 to 10^5 s, signal durations of ~ weeks to years, amplitude signal-to-noise ratios up to several thousand
Detection rate	~1/yr at $z < 2$, ~30/yr out to $z \sim 15$
Observables	Masses, $\Delta M/M < 1\%$; spins, $\Delta S/S < 2\%$ (typical detections); luminosity distances, $\Delta D_L/D_L \sim$ (5-20)% (typical detections), $\Delta D_L/D_L < 3\%$ (at $z = 1$, limited by weak lensing)
Science payoffs	Nature of black hole seeds at high *z*; history of MBH growth and galaxy mergers as function of *z*; tests of general relativity in strong-field, highly dynamical regime
Capture of stellar-mass compact objects by MBHs	
Characteristics	Compact object (black hole, neutron star, white dwarf) spirals into MBH; MBH mass of 10^4 to 10^7 $M_{\odot}$; orbital period of 10^2 to 10^3 s; signal duration ~ years.
Detection rate	~50/yr, mostly captures of 10-$M_{\odot}$ black holes at $z \sim 1$; captured intermediate-mass black holes detected to $z > 10$
Observables	Masses, $\Delta M/M < 0.1\%$; spins, $\Delta S/S < 0.1\%$ (typical detections); luminosity distances, $\Delta D_L/D_L < 4\%$ (typical detections)
Science payoffs	Measure MBH spins, which reflect their growth history; populations and dynamics of compact-object populations in galactic nuclei; precision tests of general relativity and Kerr nature of black holes
Close binaries of stellar-mass compact objects in the galaxy	
Characteristics	Close binary systems of black holes, neutrino stars, and white dwarfs in Milky Way; primarily white-dwarf/white-dwarf binaries, mass-transferring or detatched; orbital periods of 10^2 to 10^4 s
Detections	~20,000 individual sources, including ~10 known "verification binaries"; diffuse galactic foreground at frequencies below ~2 mHz
Observables	Orbital frequency; sky location to approximately a few degrees; chirp mass and distance from d*f*/dt for some high-*f* binaries
Science payoffs	~100-fold increase in census of short-period galactic binaries; white dwarf-white dwarf binaries as possible supernova Ia progenitors; evolutionary pathways (e.g., outcomes of common-envelope evolution); physics of tidal interactions and mass transfer

Table 3 summarizes the LISA top-level science requirements, and is also provided for reference.

Table 3. Top Level LISA Science Requirements Summary

Quantity	Requirement
Strain amplitude spectral density	$\sqrt{S_h}(f)=(\sqrt{5})\times(\frac{2}{\sqrt{3}})\times T(f)\times\frac{\sqrt{S_{\delta x\_IMS}(f)+S_{\delta x\_DRS}(f)}}{L}$
Single link IMS displacement noise amplitude spectral density	$\sqrt{S_{\delta x\_IMS}}(f)=\Delta X_0\times 10^{-12}\frac{m}{\sqrt{Hz}}\times\sqrt{1+\left(\frac{f_0}{f}\right)^4}$ $\Delta X_0=18$, $f_0= 2$ mHz
DRS displacement noise amplitude spectral density	$\sqrt{S_{\delta x\_DRS}}(f)=2\frac{\sqrt{S_{\delta a\_DRS}}(f)}{(2\pi f)^2}$
Single test mass DRS acceleration noise amplitude spectral density	$\sqrt{S_{\delta a\_DRS}}(f)=\Delta A_0\times 10^{-16}\frac{m}{s^2\sqrt{Hz}}\sqrt{1+\left(\frac{f}{f_H}\right)^4}\sqrt{1+\left(\frac{f_L}{f}\right)}$ $\Delta A_0=30$, $f_H= 8$ mHz, $f_L= 0.1$ mHz
Measurement Band	0.1-100 mHz
Operational lifetime	5 yr
Operating interferometers	LISA shall be designed for 3 spacecraft with 6 working links (2 interferometers) and the design shall ensure 2 operating arms for the full mission duration.
Advanced notice of merger	Identify and announce the time of a massive black hole merger at least two weeks prior to the merger
Instrument noise monitoring	Distinguish between instrumental and environmental noise and gravitational-wave signals above the sensitivity threshold when all three arms are available.
Observing interruptions	4 days uninterrupted data acquisition around merger time with 2 weeks advanced notice.

Table 3 adapted from LISA Mission Concept Document (LISA PRJ-RP-001, Iss. 1, Rev. 1, 26 August 2011, http://lisa.gsfc.nasa.gov/Documentation/LISA-PRJ-RP-0001.pdf). A comprehensive description of LISA science and sources can be found at http://lisa.gsfc.nasa.gov/Documentation/LISA-LIST-RP-436_v1.2.pdf.

Requested Information:

The response to this RFI will be in the form of a PDF document that is uploaded through NASA's NSPIRES system (see instructions below). The response should not exceed ten (10) pages in length.

The response should contain the following information:

- Name of submitter and contact information including all team members, institutional affiliations, and email addresses. Note that a lead submitter or point-of-contact must be identified (name and position, organization, email, phone number);
- Category of response: List all applicable and provide brief description of each in less than 20 words.
  - Mission concept,
  - Instrument concept,
  - Enabling technologies,
  - Other;
- Answer to these questions:
  - Will you be willing to participate and present your concept at the workshop if invited?
  - Does your organization have any sensitive or controlled information (e.g., export controlled, proprietary, competition sensitive) that might be useful for this exercise? If so, are you willing to discuss this information with NASA if proper arrangements can be made to protect the information?
- The response should be submitted in a format most effective for conveying the information (e.g., white paper, presentation charts, technical paper, other). The response should include, at a minimum, the following information:
  - A description of the concept or technology including a list of key performance and technical parameters. Performance parameters include strain sensitivity, residual acceleration noise, and/or measurement sensitivity. Technical parameters include mass, power, and dimensions. The technical readiness level (TRL) of key components should be listed. Sufficient technical detail should be provided so that the level of complexity and technical readiness can be assessed.
  - A description of how the concept or technology fulfills some or all of the gravitational-wave science payoffs (Table 2).
  - A rough-order-of-magnitude (ROM) total cost, plus a brief explanation of how this cost was estimated. The ROM cost will be used to bin concepts into the following cost categories: small ($300-$600M), medium ($600M-$1B) and large ($1B-$2B).

Future Plans

Within two weeks of release of this RFI, NASA will release an open solicitation inviting members of the astronomy community to participate in a gravitational-wave astrophysics mission Community Science Team (CST). The CST will work with the astronomy community and the PCOS Program Office in reviewing all RFI responses and defining mission concepts at various cost points between $300M to $2,000M.

As part of the definition process, NASA will sponsor a workshop this Fall (2011) to present:

a) The latest information regarding the landscape and circumstances that surround formulation and implementation of the next gravitational-wave mission (or missions);
b) A summary of the information received in response to this RFI; and
c) Potential mission scenarios for further study.

All responders to this RFI, as well as the broader community, are invited to attend the workshop and participate in this process. The workshop will serve as a forum for receiving community input for mission concept(s) definition. The CST and the PCOS Program Office will use the RFI responses and the workshop input to define mission concepts at various price points. These concepts will undergo more detailed definition and cost estimation using NASA's mission design laboratories in collaboration with the study team consisting of CST members plus PCOS Program Office staff.

The final product of this effort will be a report describing scientific capabilities that can be achieved at various cost points as compared to LISA, the science achieved by the European Space Agency's proposed gravitational-wave mission (if selected), and other science missions in the time frame of the proposed mission. The report will also describe each mission concept, its scientific capability, technical readiness and overall cost. In the Spring of 2012 the PCOS Program will release this study report to the community and present it to the CAA of the National Research Council's Space Studies Board.

Disclaimer

It is NASA's intent to publicly disclose information obtained through this RFI and to incorporate relevant portions into the workshop proceedings and the final study report. Responders shall not submit proprietary information, export controlled information (including ITAR restricted information) or confidential information in response to this RFI. It is emphasized that this RFI is NOT a Request for Proposal, Quotation, or Invitation for Bid. This RFI is for information and planning purposes only, subject to FAR Clause 52.215-3 titled "Solicitation for Information or Planning Purposes", and is NOT to be construed as a commitment by the Government to enter into a contractual agreement, nor will the Government pay for any information submitted in response to this RFI.

No solicitation exists; therefore, do not request a copy of the solicitation. If a solicitation is released it will be synopsized in FedBizOpps and on the NASA Acquisition Internet Service (NAIS). It is the potential Offeror's responsibility to monitor these sites for the release of any solicitation or synopsis. The Government reserves the right to consider a small business or 8(a) set-aside based on responses hereto. As part of its assessment of industry capabilities, NASA-GSFC may contact respondents to this Request for Information (RFI), if clarifications or further information is needed. Respondents will not be notified of the results of the evaluation.

Instructions:

All responses submitted in response to this RFI must be submitted in electronic form via NSPIRES, the NASA online announcement data management system, located at http://nspires.nasaprs.com/. For this RFI, a response submission will take the form of a Notice of Intent (NOI) within NSPIRES. The RFI response itself will be a PDF-formatted document that is attached (uploaded) to the NSPIRES system.

You must be registered with NSPIRES to submit a RFI response. See registration instructions at http://nspires.nasaprs.com (select "Getting an account"). Neither institution registration nor an institution affiliation is required to respond to this RFI.

1. Log in to your account at http://nspires.nasaprs.com/.
2. Select "Proposals" from your account page.
3. Select "Create NOI" from your proposals page.
4. Click "Continue" on the next page.
5. Select "Request for Information: NNH11ZDA019L (Concepts for the NASA Gravitational-Wave Mission)" from the bullet list of announcements. Click "Continue".
6. Enter RFI response title ("NOI title" field will be shown).
7. Select "do not link at this time" for submitting organization page.
8. Click "Save" on next page.
9. It is not necessary to complete any of the "NOI Details"; all requested information must be included in the attached PDF document. Information which is entered into "NOI Details" but not included in the attached PDF document will not be considered.
10. Prepare your RFI response offline and save as a PDF document (note NSPIRES instructions on PDF formats). The response document must include the respondent's Name, institution, phone number, and E-mail address so the file is self-contained. File names format should be "Respondent Last Name - First Name - RFI". The response should not exceed ten pages in length.
11. To attach (upload) your PDF document:
    a. Click "add" under NOI attachments section;
    b. Select "Proposal Document" from the drop down list;
    c. Browse to attach your PDF file;
    d. Select "Upload";
    e. Click "OK";
    f. Your RFI document has been uploaded to NSPIRES.
12. Click "Submit NOI" button. NOTE that this does not complete the submission process.
13. Ignore any warnings about incomplete NOI elements. Ensure that your NOI document is attached and click "Continue".
14. Click "Submit". This will take you to the NOI submission confirmation page, which provides you with the NOI/RFI number for your records.

Please note: You may delete and replace form fields and uploaded documents anytime before the submission deadline. Submitted NOIs cannot be deleted.

For further information on this RFI, please contact Jean Cottam, PCOS Chief Scientist, at jean.cottam@nasa.gov. You may also contact the NASA HQ PCOS program officers, Jaya Bajpayee, PCOS Program Executive, at jaya.bajpayee-1@nasa.gov, and Rita Sambruna, PCOS Program Scientist, at rita.m.sambruna@nasa.gov. Please check http://pcos.gsfc.nasa.gov/ for the most up to date information on the program.